RUBBER, GUTTA-PERCHA AND BALATA

RUBBER, GUTTA-PERCHA AND BALATA

BY

FRANZ CLOUTH

COLOGNE

FIRST ENGLISH TRANSLATION
WITH ADDITIONS AND EMENDATIONS
BY THE AUTHOR

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Preface to the English Edition.

The interest which my work, "Rubber, Gutta-percha and Balata" (1899, B. F. Voigt, Leipzig), aroused not only in Germany, but also in America and England, has led to many requests to publish the book in an English translation. The offer of Messrs. Maclaren & Sons of London decided me to agree to this proposal, and Messrs. Maclaren have acquired the publication rights for the English edition. The last few years have largely added to our store of knowledge on the subject, particularly with regard to the countries of production, and we are able to correct and amplify the researches and investigations of Seeligmann and other prominent experts. This has led me to revise the book, so that probably it now contains all the facts which have come to light since its first publication. Thus the English edition has its origin, and I can only hope it may meet with a similar reception and the same goodwill from all those interested in the subject as the first German edition..

FRANZ CLOUTH.

Cologne-Nippes, *October* 1903.

Preface to the German Edition.

As my publication of 1873 and 1879 met with a good reception I have decided to publish a larger and more comprehensive work, brought up to date, in which everything worth knowing about indiarubber and gutta-percha is exhaustively dealt with. Amongst the publications issued during the last fifteen years dealing with the latex of plants, which have attracted attention, are the English works by Collins and Dr. Eugen Obach, and the work by the chemist, Th. Seeligmann (1896, Paris, f., Fritsch). In Seeligmann's book I found much valuable information as to the collection and production of indiarubber, and this led me to ask the author for permission to use this material in my new work. This request was readily and courteously granted. In this way the work had its origin. Besides the material already in my possession, collected during thirty-five years of study, I have also the valuable assistance of my business co-worker, Mr. Fritz Zilcken of Cologne. It is to be hoped that it may be a service to the circles interested in the latex of plants and its employment.

FRANZ CLOUTH.

COLOGNE-NIPPES, *December*, 1898.

Works of Reference used by the Author.

Prof. Dr. O. Warburg: "Die Kautschuckpflanzen und ihre Kultur," Berlin, 1900. Dr. Rob. Henriques: "Der Kautschuck und seine Quellen," Dresden, 1899. Dr. Carl Otto Weber: "Grundzüge der Theorie der Kautschuck Vulcanisation," Dresden, 1902. Reports of the Colonial Economical Committee, Berlin. "Der Tropenpflanzer," publication for tropical agriculture, Dresden. "Gummi Zeitung," Dresden. "Cologne Gazette," Cologne.—Dr. P. van Romburgh: "Caoutchouc en Getah Pertja," Batavia, 1900. —James Collins: "Report on the Caoutchouc of Commerce," London, 1872. Dr. E. F. A. Obach: Cantor Lectures on Gutta Percha, London, 1898. Henry C. Pearson: "Crude Rubber and Compounding Ingredients," New York and London, 1899. "India Rubber, Gutta Percha and Electrical Trades Journal," London. "The India Rubber World," New York.—Th. Seeligmann: "Le Caoutchouc et la Gutta-Percha," Paris, 1896. Octave J. A. Collet: "Etudes pour un Plantation d'Arbres à Caoutchouc," Brussels, 1902. Octave J. A. Collet: "Etudes sur la Gutta Percha Commerciale." D. Morris: "Plantes produisant le Caoutchouc du Commerce," Brussels, 1902. Th. Masui: "L'Etat indépendant du Congo à l'Exposition de Bruxelles," Brussels, 1897.

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I.—Introduction—Historical.

Of all the important trees which were made known to us by the great phytographical discoveries of the fifteenth and sixteenth centuries, the rubber tree is one whose extraordinary value has been recognised only in the latter half of the nineteenth century. Columbus was acquainted with the peculiar properties of a few rubber-producing plants and mentioned these in his reports, but there was a lapse of over three hundred years before a proper use was made of this valuable material, which is now the basis of a great industry. Even then the employment of the material increased slowly, and it was put to many other and quite different purposes than those which have been found useful in later times. The year 1839 marks the turning-point in the history of caoutchouc; since then the employment of it has steadily increased and the progress of the trade has been phenomenal, new uses being constantly found for the material, until to-day there hardly exists a product of nature which is more universally employed than caoutchouc. With the growing industrial use the trade in crude rubber naturally also increased, and it is now one of the most important raw products in the world's market. The planting of rubber trees and the collection of rubber has also become one of the foremost colonial problems, and will undoubtedly prove to be an excellent source of profit for tropical and semi-tropical climates.

The material was first mentioned in literary history by Gonzalo Fernandes d'Oviedo y Valdas in his "Universal History of the Indies" (Madrid, 1536, vol. v., chap. ii., page 165). He describes the Batos game of the Indians which is "like a game with balls, although played differently, and the balls are of other material than those used by the Christians." After him comes the Jesuit Father Charlevoix, who describes the "Batos" as a kind of ball of a firm but extraordinarily porous and light material: "The ball jumps higher than our balls, it drops on the ground and bounces again much higher than the hand which threw it to the ground; it falls again, rises anew (although not quite so high), and the height of the jump be-

comes slowly less and less." Antonio de Herrera Tordesillas (born 1549 at Cuellar, died 1615 at Madrid) improves the reports in his "Universal History of the Travels and Expeditions of the Castilians," and here for the first time the word "gum" is mentioned when referring to the balls used by the inhabitants of Haiti. The same author remarks (when referring to the peculiarities of "gumana") that trees exist in this island which, when tapped, produce a milk which changes into a white gum and which has an agreeable smell. Juan de Torquemada also mentions in his works "De la Monarquia Indiana" (Madrid, 1615) the use of elastic balls, and he gives the tree which produces the material the name "Ulaquahuil," or Ulé tree, a description which is still in use by the natives of Mexico when they refer to the *Castilloa markhamiana*, the *Castilloa elastica*, and ordinary rubber. The Spanish conquerors used the material for greasing or painting their linen coats and to protect themselves against rain; the water did not penetrate, but the sun rays had an evil effect on these garments.

In the meantime a few samples of the material had been brought to Europe and graced the collections of the curio hunters of that time. The samples were very expensive, one guinea being paid for an ounce.

Two Frenchmen, the scientist Charles de la Condamine and the engineer Fresneau, must be credited with having made known the new product and fixed its real origin. To solve the much discussed question of the shape of the earth and the oblateness of the poles, the Paris Academy sent out two expeditions in 1731, to visit the equator, one being under the direction of La Condamine. La Condamine was not only a mathematician, but also a naturalist; he studied the agricultural and zoological aspects, and also the natural products of Peru and Brazil, and we owe to him the discovery of quinquina (Peruvian bark). In 1736, a short time after his arrival in Quito, he sent the Academy a few rolls of a black-looking resinous material which was known under the name of "caoutchouc." With the material he sent a report in which he says, "In the forests of the province of Esmeraldas grows a tree called 'hevé' by the natives; when the bark is slightly cut a white milk-like fluid runs out which hardens in the open air and becomes black. The natives make lights of it which burn without a wick and are very bright. . . . In the province of Quito linen material is covered with this resin and the linen is used like oilcloth at

home. . . . The same tree grows on the banks of the Amazon River, and the Mainas call the resinous fluid 'cachuchu.' They make shoes of it which are waterproof, and when these shoes are smoked they have the appearance of leather. The natives also cover moulds of earth, in the shape of bottles, with the material, and when the resin is dry they smash the mould, take the pieces of earth out through the bottle neck, and have, then, an unbreakable bottle which is very useful for preserving all kinds of liquids."

In later communications La Condamine mentions the peculiar use of the caoutchouc by another native tribe. "The Amagnas, a tribe living in the middle of the American continent, on the banks of the Amazon River, make a still more curious use of the resin. They make pear-shaped bottles, on the neck of which they fasten wooden tubes. Pressure on the bottle sends the liquid squirting out of the tube, and these bottles resemble syringes (*seringues*)." Here is to be found the origin of the name which the Portuguese gave the tree supplying the rubber; they call it Pao de Siringa, and the people collecting the material are seringarios.

Owing to his other professional and scientific studies La Condamine could not continue his researches regarding the caoutchouc tree, and the investigations would probably have stopped here had it not been for the engineer Fresneau, who had taken up his abode at Cayenne and was a wise and untiring collaborator of La Condamine's. Fresneau, who seems to have foreseen the future importance of caoutchouc, searched for the origin of the tree and found it after long inquiries by the Coussaris. In a letter addressed to La Condamine, he gives the characteristics of the caoutchouc tree and tells at the same time how the Indians procure the caoutchouc. Fresneau writes: "The lower parts of the tree trunks require to be cleaned, and next vertical cuts at a slight angle are made, these cuts being deep enough to destroy the bark. The cuts are so arranged that the higher stand exactly over the lower, so as to let the milk run from one into another. On the lower part of the trunk is a leaf of the Indian cane (*Canne indica*) through which the fluid is collected and conducted to a suitable receptacle. To use the milk-like fluid of the different trees mentioned, all of which contain resins, a suitable form of clay is made. Pieces of wood are inserted in the form on the part which it is not intended to cover with the milk, thus keeping an opening

through which the clay can be extracted by making it soft with water. When the form has been made and glazed with water, the milk-like fluid is smeared over it with the fingers, and the coat of fluid dried over a smoking fire by low heat. The form has to be turned continually during the drying process to keep the coat of equal thickness. Care must be taken that the flames do not touch the coat as it would boil and thus create little holes. As soon as the first layer becomes yellow and does not stick to the fingers, a second layer is added, and the same method followed until a coat of sufficient thickness has been arrived at. The coat is then held closer to the fire, to let the water evaporate and to retain only the elastic resinous matter. The coating becomes stronger if more layers are added. Linen material, prepared with this juice, might be used for waterproof sails, divers' hose, boxes for firemen and other purposes, bags for keeping food, etc., and no fear need be entertained that these materials would acquire a disagreeable smell. But these goods can only be produced where the trees grow, as the juice dries very easily and its fluidity is then gone."

The reports of La Condamine and Fresneau induced the French botanist Fuset-Aublet, in 1726, to go to Guiana. Two years later he published a work about the flora of Guiana, in which the caoutchouc tree is described from a botanical point of view, and where it is given the name *Hevea guyanensis*. James Howison, of the Prince of Wales Islands, discovered first the genera, giving "an elastic gum wine," which Roxburg calls *Urceola elastica;* Roxburg also discovered forests on the Brahmaputra in Assam where *Ficus elastica* abounded. Coffigny described later a wine-like plant at Madagascar which is classified with the jessamine and syringa and gives, like the others, a milk-like juice, which, when dry, supplies a resin not unlike the caoutchouc.

During the time the botanists were employed in finding the origin of the plants, the chemists were studying the new resin, and at last succeeded in dissolving it. Herissant and Macquer in 1768 both presented the Paris Academy with a report upon the results of their researches, and each recommended turpentine, pure ether, and dippel oil as a means to dissolve the resins, which were not affected by water and alcohol. They suggested at the same time the usefulness of the gum solution for the production of medical probes and small tubes such as are used in laboratories. The English chemist Priestley, in 1770, drew

the attention of English scientists to the use of caoutchouc, and he recommended the material for rubbing out pencil marks. This method of using caoutchouc was introduced into France by Magellan in 1772, and since 1775 it has been possible to buy small cubes of caoutchouc in stationers' shops, which were called "indiarubber" in England and "peaux de nègres" in France. The word "indiarubber" thus found its origin, and its use has been retained to the present day. The researches of the French chemist Bernard (1780) perfected the work of Macquer and Herissant, who had already suggested other purposes for which the elastic gum would prove suitable. Fanjas de St. Fond made experiments with a variety of asphaltum or bitumen which he found in the mines of Castleton, and he describes this material as "mineral caoutchouc" which "has nothing in common with the other material." Foucroy, Bertholler, and Giobert took also a great interest in the elastic gum. Drossart made known the most simple method of making tubes, bottles, and other goods for physical, surgical, and household use out of Brazilian caoutchouc. To make little tubes he cut the bottles in strips of suitable shape, softened these by keeping them half an hour in ether, or a little longer in a volatile oil, then rolled the strips round a spindle and compressed the caoutchouc by means of a tightly wound spiral of rope. During the drying the surfaces were united, and the article received and kept the intended shape.

Here must also be mentioned the less successful researches and tests of Besson (1791), Johnson (1797), Champion (1811), and Clark (1815), who tried but did not succeed in making a caoutchouc solution for the purpose of waterproofing garments. About this time the English manufacturer Nadier invented the method of cutting the caoutchouc into threads and making these elastic tissues which superseded the method of making the thin elastics with the aid of brass coils hitherto in use. Charles Mackintosh used, in 1823, benzine for the dissolving of caoutchouc, and by this he created the waterproof industry, which has been named after the inventor.

In 1832 Chaffee & Haskins of New York founded the Roxbury India Rubber Company with a capital of $300,000, which was later on increased to $400,000 for the sole purpose of turning out waterproof garments. They produced large quantities during the winter 1833-34, but the products did not prove satisfactory, and the firm was forced to accept the return of the goods.

The practical use of the elastic material still offered many difficulties. It could not easily be worked; it required a particular machinery, and the still unperfected methods for dissolving the raw material made it difficult to give the goods the required shapes.

These difficulties were partly overcome in 1836, when (continuing the researches of Thomas Hancock) it was found that if strips of cut and rolled-out caoutchouc were energetically worked under a high temperature, the caoutchouc became a very tough material, which lost, for the moment, its elasticity, and could be moulded into any shape or form desired. Rattier, Guibal, Aubert, Gerard, and others continued the research from these points of view with gratifying results, and the new industry began to make remarkable progress.

The existence of the industry would, in spite of this, have been rendered very precarious had it not been for another invention which surpassed all others in importance. The natural caoutchouc has, besides its impermeability and its great elasticity, a third property. Under a normal temperature it is exceedingly adhesive and sticky, especially to itself. These properties increase with a higher temperature, and the material is cohesive and pitchy, at the same time giving off a very unpleasant odour which is not noticeable when it cools. The rubber becomes brittle and breaks when strained. If one thinks of the garments made with the use of caoutchouc, or of shoes made out of the raw material, by methods such as were in use at that time, the disadvantages of these properties are obvious.

The German chemist, Ludersdorf, noticed in 1832 that sulphur dissolved in turpentine took from the caoutchouc its glutinousness and viscosity, and at the same time Hayward, an American, used flowers of sulphur for lessening the adhesive property of the raw material. Neither of the two continued their researches, but were content with their half-success until the American, Goodyear, succeeded in 1839 in solving the question and producing with caoutchouc and sulphur a material which did not break at a low, and did not become sticky at a high temperature.

Charles Goodyear (born 29th December, 1800, at Newhaven, Conn.; who died 1st July, 1860, at New York) took his first ideas from the Roxbury Company, in whose interests he started his researches. He worked with all the energy of an inventor to supply the solution to this problem, believing it to be possible

in time to produce a good combination of caoutchouc and sulphur. Although, at first, he did not lack financial support, and even later found ready pecuniary help to further his investigations, in the end he expended his whole fortune in the search, being reduced to such a condition that his family lacked the necessaries of life. It took him over ten years to find the right method, but at last he was able to present to the world a most valuable invention. Goodyear's method consisted in mixing the caoutchouc with pulverised sulphur and subjecting the mixture to a high temperature. The process is called "vulcanisation," and the caoutchouc thus treated becomes "vulcanised rubber." Vulcanised caoutchouc retains its elasticity in high temperatures (up to 120° C.) and also in low temperatures (down to 30° C., and less), besides offering greater resistance to chemical influences.

The invention of vulcanisation gave suddenly to the caoutchouc industry an unlimited field of action, and during the following twenty years almost every day saw the birth of a new invention or a great improvement in the use and production of material and goods. Goodyear patented vulcanisation by mechanical means, and his co-worker, the Englishman Hancock, patented in 1871 the vulcanisation method in a sulphur bath. The chemist Parkes invented an improved method for dissolving caoutchouc in 1873, by means of a new material, bisulphide of carbon, and took out a patent for "cold vulcanisation" or vulcanisation with chloride of sulphur. We owe to the same scientist the first steps to the invention of the desulphuration of the vulcanised rubber scraps. Augustin G. Day, in 1858, took out a new patent for an improved vulcanisation, and Gérard proposed to use sulphur contained or used with an alkali for the vulcanisation of thin goods. The last invention of great importance was Goodyear's method for making hard rubber. He succeeded in producing a horny material like whalebone or ivory, by increasing the amount of sulphur in the caoutchouc before vulcanising.

Here must also be mentioned Hancock's patent for the production of rubber goods in moulds, taken out in 1816. This invention, along with vulcanisation, is the basis of all the modern rubber productions, and the two methods gave rise to the sudden growth of an industry.

In these historic reminiscences of the caoutchouc industry one must not forget to mention the experiments made during

the last ten years to regenerate the vulcanised caoutchouc and to free it from the sulphur and other mixing materials. There have also been continued trials to find either a perfect substitute for raw rubber, or at least an addition which would supplant the raw material to a great extent. In both directions many reliable and useful improvements have been made, but a solution of the problem has not yet been found, neither can any one of the inventions in this connection be described as of great importance.

II.—Natural History.

THE etymology of the word caoutchouc is carried back by La Condamine to the language of the natives of Esmeraldas, the north-eastern provinces of the present-day South American republic of Ecuador, and the origin is the Tuka word "cachu-chu." The Spaniards turned the word first into "caucho," also "cautchuc"; the Italians called it "cautschouc," and the Germans "Kautschuk." The Spaniards also gave it another term, "serringa," which the Portugese spell as "xirringa." In addition to caoutchouc the Italians call it also "gomma elastica" after the Latin "Gummi elasticum," from which source comes also the short French word "gomme" and the German "Gummi." The French designation "peaux de nègres" (negro skins) is obsolete.

Caoutchouc is a vegetable hydrocarbon made from the sap secreted by the protoplasm of the so-called intercellular veins of a large number of trees, shrubs, lianas, and several kinds of grass growing in tropical countries. The principal veins of this cellular texture rest in the interior rings of the bark, but removed from the vascular system and the hardened fibre cells, where such are to be found. They send numerous branch veins either through the bark towards the exterior, where they end close to the surface, each in the nature of a *cul-de-sac*, or, what happens less frequently, they go through the inner skins and the radiations of the pith to the pith itself and the interior, on which periphery they continue longitudinally. Created by the protoplasms, the hydrocarbon is, according to the views of several natural scientists, no longer necessary to the life of the plant after it has reached a certain age. Other scientists, on the other hand, believe that the hydrocarbon is required by the plant to supply a certain amount of nourishment.

According to G. David, the milk-containing veins of the rubber plants are single inflated cells, running longitudinally, with numerous branch arms to all the tissues of the leaves. These ramificated milk-veins are not fibre but fill tissues (*parenchyma*), which observations by David have been substantiated by the microscopic researches of Tetul, who in 1865 laid these views before the Paris Academy of Science.

When a cut is made in a rubber plant, a sap, like goat's milk,

runs out, which is called "latex." If the sap is properly treated, the microscopic globules separate and become a firm substance, which at the first is more or less white. The globules have, according to Adrian, a diameter of 2.3 micro-millimètres (1 micro-millimètre = $\frac{1}{1000}$ millimètre). If the latex is left unattended, the globules soon separate themselves from the watery fluid, and are like cream on milk; in narrow vessels they appear as flakes swimming in the water.

The properties of the latex are as follow: It has the density of cream, smells a little like amber, and mixes with water but not with naphtha or any other fluid in which caoutchouc can be dissolved. The specific weight fluctuates between 1.02 and 1.4, whereas that of caoutchouc is 0.930 to 1.03. The amount of pure caoutchouc contained is equally fluctuating: the best latex, from Para in Brazil, contains—

Pure caoutchouc	32 per cent.
Albumen and mineral contents ...	12 ,,
Water	50 ,,

Milder climates produce a prolific number of plants with a milky sap as well, but this sap contains either no caoutchouc or only very insignificant quantities which cannot be used industrially with any advantage. It can therefore be taken as an axiom that the nettle (*urtica*), poppy (*paparer*), lettuce (*lactuca*) and fig (*Ficus carica*) plants of our climates cannot be considered as caoutchouc plants, and as far as the caoutchouc industry is concerned, they are of no direct use. Only the tropical and semi-tropical climates between the 30th degree northern and the 30th degree southern latitude, or, to limit the field still further, only the inter-tropical area, produces plants which are of any service for these purposes. There, parallel with the equator, is a belt 800 kilomètres, or about 500 miles, in width, which has all the preliminary conditions for rearing caoutchouc plants suitable for the industry. The climate is warm and moist; the temperature fluctuates between 80° and 105° F.; and the average rainfall is 81.3 inches per annum. The caoutchouc plants growing in this area belong to different botanical families, comprising mainly the Euphorbiaceæ, the Artocarpeæ, the Apocynaceæ, and the Asclepiadeæ. But even with these families a difference has to be made regarding the quantity and quality of the caoutchouc produced.

How the total production influences the caoutchouc market, what circumstances react on the production from, and what are

the reasons for the better or inferior quality of caoutchouc, are points which will be considered later. It is first necessary to take into consideration the latex-producing plants and to describe them botanically. The following tables give in a condensed form the names of the known caoutchouc plants, and the geographical maps show the areas in which the different families occur.

The caoutchouc plants can be divided into the four following families :—

1. *The Euphorbiaceæ.*
   Heveas, Micranda, Manihots, Euphorbia.
2. *The Ulmaceæ* (a genus of the Artocarpeæ).
   Several species of Castilloa, Ficus, Artocarpus, and Cecropia.
3. *The Apocynaceæ.*
   Landolphia, Urceoles, Dijerea, Hancornia, Cameraria, Parameria, Leuconotis, Artodendron, Alstonia, Chonemorpha, Kickxia, Carpodinus, Clitandra.
4. *The Asclepiadeæ.*
   Callotropis, Cynanchum and Periploca.

FIG. 1.—Kickxia Africana (see page 39).

Tabular Synopsis of Plants

Genus.	Species.	Synonyma.	Local Name.	Botanist.
				I. Euphor-
Hevea (Siphonia)	Hevea guyanensis	Siphonia elastica Jatropha elastica	Xirringa Hévé Cahuhu	Aublet, Linné, Schreber Pers, Willd., Richard, Gmelin, Fuss
	Hevea Spruceana	Siphonia spruc.		Müller von Aargau, Benth.
	Hevea lutea	Siph. lut. „ apiculata	Long - leaved Xir. Short - leaved Xir.	Müller v. Aarg. and Spruc.
	Hevea brasiliensis	Siphonoïdes bras. and Siph. kuntiana		Müller v. Aarg. Mark and Benth. Kunt, Willd.
	Hevea rigidifolia	Siphonia rigid.		Müller v. Aarg.
	Hevea brevifolia			Müller v. Aarg.
	Hevea apiculata			
	Hevea confusa			

supplying Caoutchouc.

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
biaceæ				
• Brazil, Rio Negro, French and English Guiana, Peru, East Ecuador, Bolivia, Venezuela				Acclimatised at Réunion, Ceylon, in British India, Cochin-China, Tonkin, Annam. Stem 50 to 60 feet high, 2 to 2½ feet in diameter; thin grey bark; white, light wood.
Para, Tapajas-mauth				Stem smaller, as the Hevea brasiliensis.
Brazil (Rio Negro, Cassiquiare)				Stem 70 feet, less latex as H. br. These three species differ little. The latex of the H. lutea gives black spots which cannot be removed from linen. Very elastic and strong.
Brazil, Para, Venezuela				Stem 60 feet high. Supplies mash latex and best caoutchouc. Much milky sap. 80 feet high.
Colombia, Rio Naupes				Slender, high shooting, thin stem with thin smooth bark; strong fragrant flowers. Gives little latex. Dr. Sprice says that stem reaches at San Carlo 100 feet in height.
Brazil (Rio Negro, Cassiquiare)				Stem 25 feet high, horizontal, wide, branching boughs. Little latex. Caoutchouc not very elastic.
British Guiana				

Genus.	Species.	Synonyma.	Local Name.	Botanist.
	Hevea discolor	Siphonia discolor. (Micranda ternata)	Xirringa de gasso	Müller v. Aarg. and Benth.
	Hevea membracena			Müller v. Aarg.
	Hevea pauciflora	Siphonia paucifolia		Spruc., Benth., M. v. Aarg.
	Hevea Benthamina			M. v. A.
	Hevea Caoutcha		Para blanc, Virgin Sheets	Gmelin, E Carrey
Micranda	Micr. major „ siphonoides „ minor			Benth „ „
Manihot (Maniok)	Manihot Glaziowii		Manisoba Leitera	John Smith
	Sapium biglandulausum		Lechero	M. v. A.
Euphorbia	Euph. rhipsaloides			Welwitsch

II.—Ulmaceæ

Castilloa	Cast. elastica		Ule tree, Ulequahil, Ulequahuitl, Hule, Jebe, Tassa	Cervantes

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
Upper Amazon, Rio Negro, Rio Naupes				
Colombia, Upper Amazon, Rio Naupes				
Engl. Guiana, Colombia, Rio Naupes (mountainous part)				Very strong stem, 40 to 50 feet high. Very rich in sap.
Upper Amazon (Brazil), Rio Naupes				
Brazil (Matto Grosso)				
„ (Amazon)				
„ „				
„ „				
Ceara				Acclimatised on the coast of Gabon, in the Congo, Ceylon, German East Africa, etc.
Venezuela (Aragua Valley)				
	Angola			
(Artocarpeæ).				
Mexico, Colombia, Ecuador, Middle America, Antilles, Martinique				Stem of 6 to 8 feet circumference, plain bark. Branches and leaves alternate. The leaves pilose on both sides. Acclimatised at Martinique, where the stem only reaches 5 to 6 feet circumference.

Genus.	Species.	Synonyma.	Local Name.	Botanist.
	Cast. markhamiana		Ulé-Ulé	Coll.
	C. Tunu		Tunu	
Artocarpus	Artocarpus integrifolia		Breed tree	Roxburg
	Artocarpus elastica		Benda, Buda, Truup	Herb. Rudt. Blum
Cecropia (Moreen)	Cecropia peltata			Meyer Mart.
	Surinamensis			
	Adenpus			
Ficus (Moreæ)	F. Vogelii		Aba	Miq.
	F. Holstii		Msoso	Warburg
	F. usambarensis			Warburg
	F. Preusii			Warburg
	F. trichopodo			Back
	F. indica		Cashmir, Banjan	L. Roxburg
	F. elastica		Karet, Karet-Tapok, Pohon-Karet, Kohlet	L. Roxburg, Blume, Kurz

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
Panama, Colombia, Costa Rica				
British Honduras				This kind is said to supply a caoutchouc which is not elastic, and resembles balata and gutta-percha
		Assam, Burma		
		Sumatra, Java		
Rio Negro, Dutch Guiana				
	Gold Coast			
	German E. Africa			
	German E. Africa			
	German E. Africa			
	Madagascar			
		Bengal, Assam, Burma, Singapore, Siam, Malacca, Philippines		
		Bengal, Prince of Wales' Islands, Malacca, Cochin-China, Annam, Tonkin, Java		In Europe, a garden plant, imported from India (Botanical Gardens at Calcutta)

Genus.	Species.	Synonyma.	Local Name.	Botanist.
	Fic. primoides		Banut-Kalodja	L. Roxburg
	Fi.c religiosa			Willd., Roxburg, Linné, Blum
	Fic. altissima			Blum
	Fic. lacifera		Hyoung-Pen	Miq., Roxburg
	Fic. obtusifolia		Hyoung-Hyap	Rob.
	Fic. glomerata			Willd.
	Fic. oppositifolia			Willd.
	Fic. macrophylla			Desf., Roxburg
	Fic. rubiginosa			Desf., Roxburg
	Fic. annulata			Blum, Kurz
	Fic. gameleira			
	Fic. subcalcrata			
	Fic. radula			Willd.
	Fic. pertusa			L.
	Fic. crassinervia			Desf.

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
		Bengal, Java		
		Sumatra, Java		
		Assam, Pegu, Siam		
		Chittagong, Siam, Malacca		
		British India		
		British India		
		Java, Sumatra, Indian Archipelago	Australia	
		Java, Sumatra, Indian Archipelago	Australia	
		Pegu, Siam, Malacca	Australia	
Venezuela				
Guadeloupe				
Guadeloupe				

Genus.	Species.	Synonyma.	Local Name.	Botanist.
	Fic. lentiginosa			V.
	Fic. medina			Kahl
	Fic. tammako		N'daba Touronin Koko, N'zéné Touron	
	Fic. racemosa			
	Fic. incisa		Banian	E. Davillé
	Urostigma Vogelii lacifera	Ficus lac.		Vogel, Roxburg
	Urostigma Vogelii prinoides	Ficus prin.		Miq., Willd., Humboldt
	Urostigma prolixa	Ficus incisa	Banian	
	Melodinus		Sadal-Kowa	
	Diander			

III. Apocy-

Landolphia (Vaheas)	L. madagascariensis	Echites, Faterna elastica	Voaéne, Voahéré, Voa Canja, Vonhéma, Vaheigne, Mondrésy	Boyer, Siele, Dewèvre
	L. senegalensis		M'bungu, Angauan	A. D. C. Dewèvre

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
uadeloupe				
	Senegambia, Soudan			
	Senegambia, Soudan			Of the following African Ficus trees it cannot be said that they supply a useful caoutchouc; each kind must be tried.
	South of the Ivory Coast			
			New Caledonia	
	W. Africa, French Guinea, Great Bassam, Liberia	Assam, Java, Ceylon		
ew Granada				
			New Caledonia	
		Bengal		
	Sierra Leone			
aceæ.				
	Madagascar			The Landolphias, of which the three first mentioned were formerly known as Vaheas, are excellent African caoutchouc plants, and supply a good and often a superior caoutchouc.
	Senegambia, Portuguese Guinea			

Genus.	Species.	Synonyma.	Local Name.	Botanist.
	L. commorensis		Voa Hiné	Boj, Dew.
	L. Foreti			Dew.
	L. Klainii			Dew.
	L. tomentosa		Toll Folé	Dew.
	L. lucida			K. Schw.
	L. angustifolia			Dew.
	L. Tholonii			Dew.
	L. parvifolia			Dew.
	L. crassipes			Dew.
	L. capensis			Dew.
	L. delagoensis			Dew.
	L. Pericri			Dew.
	L. Michelinii			Dew.
	L. owariensis	Pocderia ow.	Licomque	De Beauvais, J. Collins, Spreng. Welwitsch, Dew.
	L. Hendelotti	L. Traunii	N'dambo	D. C.

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
	Comoren (islands), Madagascar and from Senegambia to Angola			
	Gabun			
	Gabun			
	Upper Guinea			
	Congo			
	Usambara			
	Congo			
	Angola			
	Madagascar			
	Transvaal			
	Delagoa Bay			
	Madagascar			
	Upper Guinea			
	Owar, Benin, Sierra Leone, Liberia, Gabun, Congo, Angola, and the Slave Coast			
	French Soudan, Portuguese Guinea, Senegal, E. Africa			

Genus.	Species.	Synonyma.	Local Name.	Botanist.
	L. florida	Niger flora	Rituti, Aboh	Bentham, Welwitsch
	L. Kirkii		Matire, M'tiri	Kirk
	L. petersiana		Mtolia, Matatu-Bousu	
	L. Manii			
	L. wassonita			
Tabernæ-montana	T. stenosiphon		Paulirio	
	T. angolensis		Catagrande	
	T. crassa			
Willughbeia	Willughbeia edulis		Luti, Am. Scan-dart Mango	Roxburg, Kurz
	W. Turbidgei	Martabianca		Wall.
	W. Treacheri	Javanica		Blum
	W. firma	Corvacia		Blume, Wall.
Urceola	U. elastica	Elastic gum wine	Guttah, Gettha, Giétan, Gutta, Susu	J. Howinson, Roxburg, Sprenz.
	U. esculenta	Chavanesia esculenta		Benth.

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
	Angola, Liberia, Middle and East Africa			
	Zambesi, Zanzibar, East Africa			
	East Africa			
	East Africa			
Virgin Islands, especially St. Thomas and Rolas				Supply so little caoutchouc that it does not pay to collect the latex.
	Madagascar, St Maurice	Ind. Arch., Burma, Bengal, Chittagong, Java, Silhet	Australia (acclimatised)	
		Ind. Arch., Martaban, Chittagong	(acclimatised)	
		Ind. Arch., Java	(acclimatised)	
		Singapore, Sumatra	(acclimatised)	
		Ind. Arch., Borneo	(acclimatised)	
		Ind. Arch., Siam, Tenasserim,	(acclimatised)	

Genus.	Species.	Synonyma.	Local Name.	Botanist.
Dijera	Dijera edulis	Cortulata		John Hooker
	„ Lerii			
Hancornia	Hanc.speciosa		Mangabeira, Mangabiba, Palo de Vaca (Venezuela)	Gomez, Markgraff, Müller von Aargau
	Hanc. minor			M. v. A.
	Hanc. maximiliana			A. D. C.
	Hanc. Lundii			A. D. C.
	„ Gardeneri			M. v. A.
	„ pubescens			M. v. A.
	„ floribunda			Poepping and Endlicher
Cameraria	Cam. latifolia			
Parameria	Par. glandulosa			Pierre
Leuconotis	L. eugenifolius			
Anodendron	A. pausculatum			
Alstonia	Alst. constricta			
Chanemorpha	Chan. macroph.			

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
		Malacca, Borneo, Sumatra, Moluccas, Philippines		
		Borneo		
Pernambuco, Maranaham, Peru, Venezuela, Minas Geraes				The Hancornias supply an excellent caoutchouc, known in the trade under the name Mangabeira cauotchouc.
Rio de Janeiro, Rio Negro, Peru				
Peru				
,,				
,,				
,,				
,,				
Peru				
		Indo-China, Annam		
		Ind. Arch.	Australia	
		,,		
		,,	,,	
		Malacca		
		Ind. Arch.	,,	

Genus.	Species.	Synonyma.	Local Name.	Botanist
Kickxia	K. africana		Okeng, Ofuntum	Benth. Dr Preuss
	K. elastica		Iré, Ireh	
	K. latifolia		Ereh	
Carpodinus	C. lanceolata		Otarampa	
Clitandra	C. henriquesiana		Bihungi	
				IV. Ascl
Callotropis	Cal. gigantea		Fafetone, Wadoré, Sidagori, Madori	R. Brown
	„ procera		Algodun de seda	R. Brown
Cynanchum	Cyn. ovalifolium			Wight
Periploca	Peripl. græca			

Euphorbiaceæ.

The Hevea is a genus of the Euphorbiaceæ, which is classifie as a jatrophean. The flowers are dioecious and aphyllous; th calyx is quinquepartite and often slightly turned on the points The ovary of the female flower is in most cases surrounded b glands which grow either separately or are connected. It con sists of three flabelliform leaves, on which rests a pistil in th form of a pillar ending in a divided, fleshy, and grained lobule The fruit, which according to Aublet is eatable, is a capsul with three seed-vessels, each one opening into two putamens The outer part of the fruit is fleshy before ripening, and ca easily be detached from the inner part. The Heveas are larg

Where Found.				Observations.
America.	Africa.	Asia.	Australia.	
	On the West Coast from Sierra Leone to the Congo State and the whole hinterland.			Only known since 1894; cultivated in Cameroon.
	Congo State			The so-called root caoutchoucs come from these two plants.
	"			

piadeæ.

	French Soudan	Assam, Batavia		Assam has supplied little good caoutchouc in later years.
Venezuela (Terra Caliente)		Penang, Siam, Malacca		Imported from East India.
	Réunion			

trees containing much-milky sap. Their leaves stand alternate, are long, petiolated, and digitate; three firmly attached and petiolated sepals have glands on the lower part of the cup. The flowers are racemes, consisting of terminal cymes; the middle flower of each cyme is generally female. The tree can easily be propagated; the capsule containing the seed opens with a detonation like the explosion of a rocket, and the seed is spread over 15 to 20 mètres (= 50 to 70 feet) of the ground. The procreation is absolutely left to chance.

Until recently the *Hevea guyanensis* (Linnæus calls it *Jatropha elastica* and Schreber, *Siphonia elastica*) has been mentioned as the caoutchouc tree called by the Brazilian Indians seringa or cahuhu, but this is not correct. The *Hevea guyan*

ensis is the tree described by La Condamine and Fresneau, but it gives only little latex, and even this does not contain the best caoutchouc.

The Hevea growing the best caoutchouc is the *Hevea brasiliensis* (Mueller of Aargau) or *Siphonia brasiliensis* (H. B. K.).

The *Micranda*, also a species of the jatrophea, is a tree like

Fig. 1*a*.—Hevea brasiliensis.

the Euphorbiaceæ, with flowers without seed-vessels, whose petals are imbricated. The ovary is trifid, the fruit opens late, and this is not always sure. Three or four genera of the family with alternate leaves are recognised. Their home is in Brazil.

The *Manihots* (*Plum—Adams*) are a variety of the jatrophea. America counts seventy-five species of these bushes and grasses with alternate digitate, lobated, and partite leaves. The roots are ventriculous, rich in starch, and they are used in the tropics as human food.

The *Manihot Glaziowii* or leitera supplies the caoutchouc which is called "manisoba" by the natives, and has a trade name, Ceara scraps. It grows on dry, stony soil in the mountains, whereas the Hevea can only be found in the lowland in an argillaceous soil.

The *Euphorbeas* have a sharp, caustic, emetic, and epispastic sap. Until now only little use has been made of them, but it is to be expected that an improved yield of the caoutchouc contained in it will be obtained.

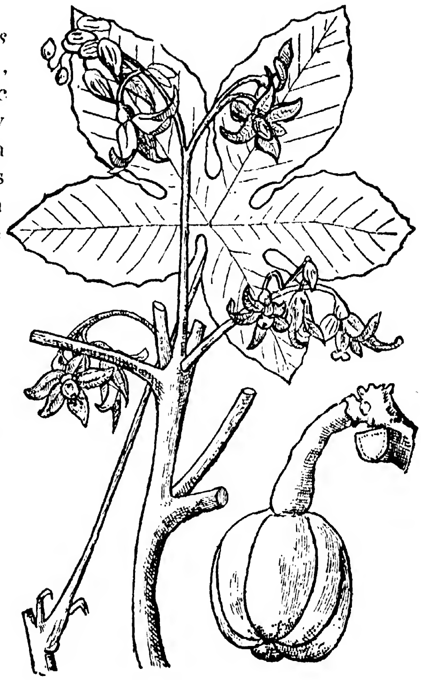


Fig. 2.—Manihot Glaziowii.

Ulmaceæ.

The Castilloa, a species of the Ulmaceæ, belongs to the family of the Artocarpeæ. It has monoecious flowers resting on flat capitulums of numerous imbricated stipules. The male flowers have no perianth, but are only composed of stamens. The female flowers, which have numerous pericarps on a common thalamus, have a quadripartite calyx and an ovary which is overhung by a cylinder-like pistil. The pistil branches in its upper part into two straight, scarred, twisted, or subulated threads. The Castilloa gives, when ripe, a nearly dry drupe, which is synantherous with the calyx, and it contains a seed corn without a perisperm. The tree is mostly pilose and has distichous difformed leaves, which are surrounded at the bottom by concreted stipules.

The *Ficus* belongs to the family of Ulmaceæ and to the Artocarpeæ. It is best known by its uni-sexual flowers in the pyriform or globular thalamus. Male and female flowers stand often on the same scapes, the male on the top and the female

underneath, but in most cases each sex has a separate scape. The single flower is very small and simple, it has a thin-skinned, infundibuliform calyx consisting of six to twelve leaves with either three stamens or a thalamus which harbours a pistil. The wall of the scape swells after the flowing and becomes fleshy; often small quantities of sugar can be found in it. The scape develops into small monospermous nucules.

FIG. 3.—Castilloa elastica.

The Ficus genus includes large trees; bushes, and creepers (lianas). The leaves stand generally alternately, seldom opposite, and different forms can be found in one and the same species. They are either entire or palmatedly lobated, rough or bold. On the end of each branch is an acicular green bud, which consists of one or more rolled stipules underneath which lie the real leaves. The scape grows single or in tufts directly out of the branches or the stipules; it is seldom that they form spikes or terminal grapes. The genus of the Ficus is very abundant; at least 600 species are native to the tropics and the inter-tropical regions. Large numbers of these trees are found in the Indian Archipelago and the islands of the Pacific. The Castilloa is the caoutchouc tree of Mexico and Central America, and the Ficus is the same to Australia and East Asia. It is seldom to be found in America or Africa.

Of the Ficus species, the *Ficus elastica*, well known as a hot-house or garden plant, has many friends in Europe. To thrive

in our climate it requires moderately warm air, and for a part of the year it can be kept in the open, but at the first sign of frost it must be taken indoors. This plant can also be grown in pots, but it grows much better in the free soil. The multiplication is easy. Let a few young shoots grow until they have four or five leaves, and use these as cuttings the following spring by putting them in a bottle with water, when out of the cut surface little white roots will slowly develop. A light soil mixed with leaf or heather earth is the most suitable for the rubber plants.

Fig. 4.—Ficus elastica.

The Artocarpus (Bread Tree) is a tree belonging to the Ulmaceæ. A division of the Ulmaceæ has been named by several botanists Artocarpeæ. The flowers are monoecious. The male flowers have a bipartite to quadripartite, more or less deep, imbricated calyx and only one stamen; the female flower has a hollow tubular thalamus, which grows out of the common thalamus of the inflorescence. The female flowers rest on a bivalvular border which comes forth from a spadix. Through mutual growing together of the legumes of the female flower which become flashy after the fading, the whole spadix becomes one common seed body of a farinaceous substance and round or oblong shape. In Asia and Australia about twenty species are known. The trees have a milky sap, soft wood, and alternate palmated or sinuate notched, but seldom entire leaves. On the stipule are two concreted stipules in the shape of a broad sheath, which surrounds a new branch and leaves a stigma after falling off.

The latex of the Artocarpus is sticky and is mainly used by the natives for the production of birdlime. The fruit is, as a nourishing food for the South Sea Islanders, of the greatest

importance. The trees grow to a height of 15 to 20 mètres—50 to 70 feet.

Cecropia (Loefl.) is a genus of the Ulmaceæ of the family of the Conocephales. The flowers cluster like dense spikes. The calyx of the male flower has on its point two small holes, two stamens, short thread-like filaments, and a bilocular anther. The calyx of the female flower is tubular and a little thicker on the top. The ovary is unilocular and has on its point a capitate stigma. The Cecropia produces awns surrounded by the calyx.

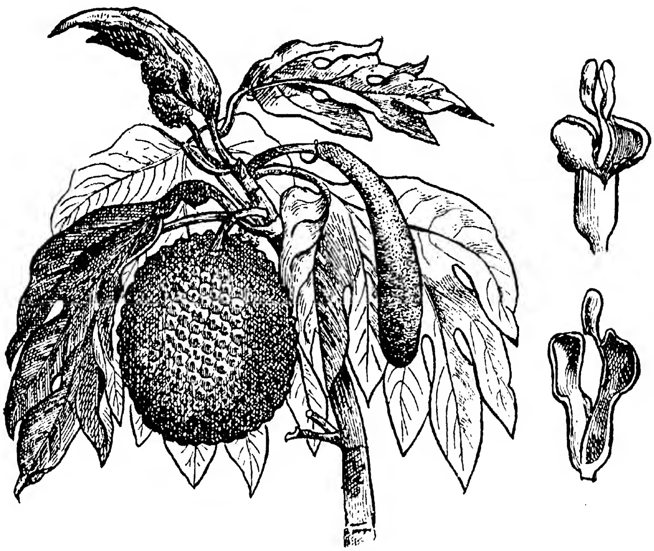


FIG. 5.—Artocarpus.

The nodular branches have a hollow space between the nodes. The leaves stand alternate and are palmatedly lobated. The tree has its home in Central and South America.

Apocynaceæ.

Vahea is a species of the Apocynaceæ and about twenty kinds are known in Central Africa and Madagascar. The flowers stand in cymes; the corolla is an infundibuliform tube in which are enclosed the stamens. The fruit is a big berry with eight angular seed corns with hard perisperms. Whereas formerly the Vaheas were considered a separate kind of the

Apocynaceæ (M. Radelkoffer), but now the plants are included (K. Schumann) with the

Landolphias, and are identified with these. The Belgian botanist Alfred Dewèvre, who died at the Congo, counts in his monographical studies since 1895 nineteen kinds of Landolphia; since then Pierre (1898) has added two more and Funelle describes a third. It is hardly likely that the whole of the Landolphias are included in this list or even known.

The Urceolas, a genus of the Apocynaceæ-Nericeæ, include six lianas which have their home in the Malayan Archipelago, and this group of Ecdysanthereæ is remarkable for its glandless calyx flowers. The corolla is mostly fascicular, often slightly twisted. Between the corolla and the thalamus is an undivided or quinquepartite roll.

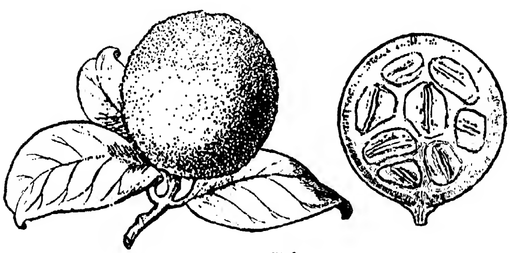


FIG. 6.—Vahea.

The Hancornias have a quinquepartite calyx; they have no glands. The corolla is plate-shaped with a narrow inner laniferous tube. Five stamens are enclosed in the corolla tube, they have long and thin filaments and no nectary. The spindle-like plain ovary is divided in two cells by a thick and fleshy dissepiment, in which numerous little ovules are impressed on both sides. The fruit is a round or pyriform, fleshy and milk-containing berry; it contains numerous seed corns which lie in the flesh of the fruit and have a hard perisperm. The Hancornias are small milk-sap containing trees with entire, alternate, sessile, sub-peduneulate leaves and fragrant flowers. The fruit of the *Hancornia speciosa* (Gom.) and the *Hancornia pubescens* (Nees and Mart.) is known by the name "mangaba" and held in high esteem by the natives.

Cameraria (Mueller) belongs to the Apocynaceæ of the division Plumericeæ. The flowers have no rolls, the anthers of the stamen are overhung by a long thread. The ovary is

bilocular and polyspermous, the fruit is a hard, double samara. The Cameraries are smooth cordicose bushes with terminal leaves and groups of flowers in terminal cymes. The species is mostly to be found in the Antilles.

The *Cameraria lucida* and *latifolia* (Jack) supply caoutchouc.

Parameria (Benth.), a species of the Apocynaceæ-Nericeæ

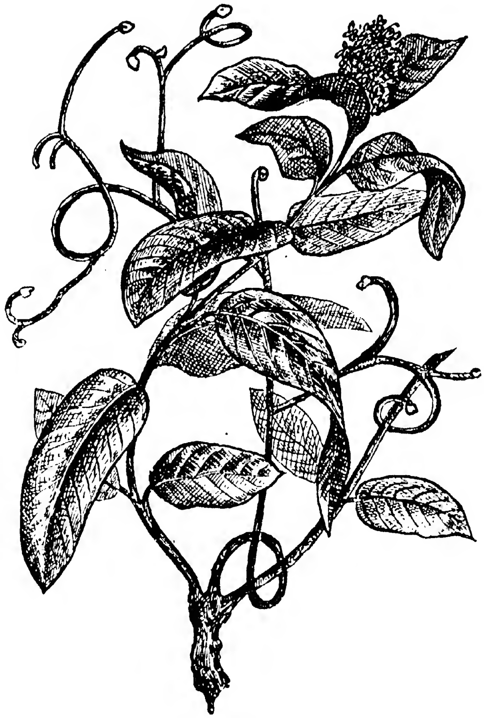


FIG. 7—Landolphia owariensis.

and related to the Ecdysanthereæ, are remarkable for their calyx, which has in its interior several glands, the quinquepartite corolla, and the elongated fruit, which swell at the point where the seed is contained. To this species also belong the two or three genus of lianas which are native to the Asian and Oceanic tropics. The *Paramera Pierrei*, well known in Cambodia, supplies an excellent caoutchouc.

Leuconotis (Jack), a species of the *Apocynaceæ Carisseæ*. To this class belong two milk-sap-containing shrubs, growing

in the Malayan Archipelago; the ovary is bilocular, the fruit fleshy, and the seeds have no perisperms.

Alstonia (C.). The flowers are androgynous and regular, the calyx is quinquepartite, the corolla plate-shaped and twisted in the buds, with five enclosed stamens. The fruit consists of two long and small capsules which contain a great quantity of seed with pilose episperms. The Alstonias are handsome trees with alternate leaves; they are native to the Asiatic and Australian tropics. The flowers are composed of racemes. The latex is very bitter.

Chonemorpha (G.), a genus of the Apocynaceæ family and the sub-branch of the Euchitideæ. The calyx is a short quinquefid tube, with glandular rolls on the interior. The corolla is infundibuliform; the stamens are enclosed and the filaments are wide and very short. The ovary is bilocular and surrounded by a thick roll. The fruit, which is not unlike a pilose crown, consists of two triangular capsules with numerous seeds, which have sharp points on their rostrate ends. The Chonemorpheæ are vine-like creepers with alternate broad, pinnated leaves and beautiful large white flowers which grow in umbels. Two or three species are known which are native to the Malayan Archipelago and the East Indies.

Kickxia. The Kickxias have been known on the Gold Coast as caoutchouc-supplying plants since 1882, but their great value only became recognised in 1894 (Lagos). Since then they have received much attention, and it is very probable they will play an important rôle in caoutchouc production since it seems clear that they are suitable for transplantation. The trees are 50 to 65 feet high with straight, nearly circular stems often over 3½ feet in diameter with a pyramidal crown. The leaves are like those of the Arabian coffee tree. The plants belong to the family of Landolphias. Besides the first-known *Kickxia africana* (Benth.), Dr. Preuss mentions also the *Kickxia elastica* and the *Kickxia latifolia*, but without doubt there exist still more of the genus and species. They are to be found on the the African west coast and in Sierra Leone up to the Congo State and far down to the hinterland, very likely to the centre of Central Africa.

Carpodinus and *Clitandra* are two plants belonging to the Apocynaceæ; these plants crawl in the sand, but the parts over the ground have no climbing powers. The plants have stems 8 to 24 inches long with alternate leaves in groups of three and

syringe-like flowers. Their home is in the Congo State, and in some parts whole districts are described as covered with these plants. The *Carpodinus lanceolata* and the *Clitandra henriquesiana* are best known as caoutchouc-supplying plants; the caoutchouc is taken from the finger-thick root branches, and it has in the trade the collective name "root caoutchouc."

Asclepiadeæ.

Cynanchum (L.), a plant of the Asclepiadeæ and the division of the Cynacheæ, is remarkable for its quinquepartite calyx with five to ten glands on the interior, a rotate corolla with quinquelobate edges, and a ten-lobed stipular crown. The stamen is enclosed in the corolla, and the filaments are grown together to a very short tube; the episperm of the anther is inflected. It has smooth double utricles with crotched seeds. The creeper has alternate, mostly cordate leaves and small flowers, which grow between the petioles and stand as corymbs.

Periploca graeca (L.), a species of the Asclepiadeæ with grainy pollens which rest in a receptacle widening in its upper part. The corolla is rotate, twisted, and has a stipular crown with short wide leaves. It is not seldom that aphyllous creepers contain milk sap.

Calotropis procera (R. Br.), an Asclepiadea with alternate, cross-wise standing, obovate leaves, which are smooth on the upper end and have white woolly hair on the lower part. The flowers stand in compound umbels; the peduncle is pilose, the corolla is campanulate with a quinquepartite edge, and it sits in a cornered tube. The filaments are grown together. The flowers are large and beautiful, and of rose and purple red colour. The utricles are short and run to a sharp point; they contain pilose seeds.

Spatinus.

As the vascular system of the rubber milk in the different families of the caoutchouc-producing plants is not always the same, a few remarks, mainly from Sach's treatises (Paris, 1874) on this botanical subject may be added.

The vascular system of the milk from the Urticeæ, which is especially developed in the Ficus species, runs in the bark in immediate proximity to the liber fibre. The Ficus shows also milk veins in the pith, but these are never so numerous or so strongly developed as in poppy plants, or so regularly ramulose as the Chicoraceæ. In the space between the nodes of the

stem are milk vacuoles like long, uninterrupted, cylinder-shaped tubes, which do not branch out frequently, and it is seldom they enter into communication with neighbouring tubes. In the nodes and the leaves the vascular system can always be observed, net-like and ramulose, with small and fine extensions, which end like a *cul-de-sac*. In many Ficus species, the vascular milk system nearly reaches the surface of the outer skin of the leaves.

The milk vacuoles of the Euphorbiaceæ are, in their ramifications, like those just described, and the branches extend all over the parenchyma, but the dissepiments between the tubes are stronger and in sections look more like liber fibre. They show their best development near the vascular system of the liber, which is often supplanted by them; from this point the veins go into the bark and the pith, and in the nodes of the caulis and the leaves they become very ramulose.

The milk vacuoles of the Asclepiadeæ and Apocynaceæ are still more like the fibre of the liber, and as in these, the dissepiments are thick and characteristically striated. They often supplant the liber fibre, and occasionally unite with the vascular system of the fibre, and the latter has also been surrounded by the milk-carrying veins. Through the existence of the milky sap the relationship of the transformed liber fibre with the real milk vacuoles is shown; the more milk they contain the thinner become the dissepiments. Besides these fibre vacuoles, very ramulose tubes can be observed, especially in the nodes, the pith, and the bark.

It will be understood that not only the quantity of the milky sap in the various species differs, but it also depends on the age of the plants, the condition of the soil, the season, and when the collection has taken place. It is equally self-evident that the quantity of the milky sap, and consequently, the caoutchouc, depend largely upon the means by which the latex has been collected and how the rubber globules have been separated from the whole fluid.

The *Hevea brasiliensis* can only be obtained when the trees have reached an age of fifteen to twenty years, and only when twenty-five have they reached their full development, which they retain until they become centenarians; the Manihot becomes useful when ten and the Urceola when only five years old. The climate has a decided influence on the quality and quantity of the latex. A tropical climate is on the whole essen-

tial to a successful cultivation of the trees, and the temperature ranges in Brazil 70° to 120° F. Great differences can be observed in a semi-tropical climate, say between the 30th degree northern and the 30th degree southern latitude, and a plant which grows luxuriantly in Brazil cannot always be successfully acclimatised in India.

According to the climatic conditions, the most important caoutchouc plants can be divided into the following geopraphical groups :—

South America (Valley) . .	Heveas.
,, ,, ,, . .	Micrandas.
,, ,, (Mountains) .	Manihots.
,, ,, ,, . .	Hancornias.
Central ,, ...	Castilloas.
West Africa	Landolphias.
,, ...	Kickxias, Collotropis.
East and Central Africa . .	,, Landolphias.
,, ,, . .	Carpodinas.
,, ,, . .	Clitandras.
Asia	Ficus, Willughbeias.
,, ...	Cynanchum, Camerarias.
,, ...	Chavanesias.
Australia	Ficus, Urceolas.

For a long time it was assumed that caoutchouc plants required a damp climate and a soil exposed to the tropical sun, but this applies in reality only to the *Hevea brasiliensis*. The Hancornias can be found in the sandy districts of Pernambuco, Maranhao and Bahia, and the Manihots grow on the precipitous granite rocks of Ceara. The last-mentioned plants are able to withstand an extraordinary drought; when everything else perishes from the fervid heat these plants flourish and supply great quantities of latex. The caoutchouc plants always grow best where the soil is subjected to inundations and a regular rainfall. If the climate and the soil are too damp and moist the latex becomes watery and contains little caoutchouc, whereas the quantities of caoutchouc are much greater in dry seasons, although the latex is less and it takes much more trouble to collect it. The caoutchouc contained in the latex fluctuates between 15 and 40 per cent. If it is under 15 per cent. the collection of the latex or the growing of the trees does not pay.

Taking into consideration the importance of the crude rubber in such a growing industry the idea of attempting to cultivate caoutchouc trees in other portions of the globe than where they were originally found was a very obvious one. It was Englishmen who made the first successful attempt to transplant and acclimatise these plants in Asiatic colonies, where the needed climate and a fitting soil could be provided. The pioneers were much encouraged in the attempt to make India the premier country as regards the cultivation and supply of rubber, as many reasons made the successful issue of such an undertaking almost certain. The caoutchouc production on the Amazon River was conducted on such irrational lines that most of the trees succumbed under the treatment, and the "seringueiros" were forced to explore the virgin forests to their farthest corners. Besides this, Brazil charged a high export duty on rubber, for which 20 to 22 per cent. of the full value had to be paid. These conditions arrested the attention of the legislative bodies appointed to look after the interests of industry and trade. It had to be taken into consideration that a rational culture of rubber trees in India would be very expensive, and the profit to be made was not quite assured when one accepted the fact that the Brazilian forests held abundance of material where the only cost was the price of collection. On the other hand there was the great difficulty of gaining access to the country where nature produced the latex; the journey occupied some weeks and was by no means a cheap or an agreeable one. In addition, the cost of transport for the rubber was an equally serious item. Another point was that the production was confined to the dry season, which reason increased the cost of the material. The English Government had learnt a lesson when planting the cinchona, and this example had not been forgotten. The necessary energy and attention were therefore at once given to the problem.

The first trial was made in 1860 with a closed plantation of native Ficus trees. The Ficus can only supply sufficient latex worth mentioning when twenty-five years of age, and even then it is only permitted to tap the trees every three years. To expect more from these trees would be to quickly destroy them. When fifty years old each Ficus tree can supply about 45 lb. of caoutchouc at a three-yearly gathering.

This calculation and the prolonged time of waiting was not very enticing, and repeated trials had also shown that the

caoutchouc obtained could not stand a comparison with the quality from Para and Ceara. It was decided not to continue the planting of this species. Some recommended the *Urceola elastica*, which can be tapped three years after planting, also the *Urceola esculenta*, which supplies caoutchouc when seven years old and the annual collection from each tree comes to 1 to 5 lbs. The best planting results were obtained with the *Castilloa elastica*, but its caoutchouc is of very little value. The Directors of the Botanical Gardens at Kew sent, in 1875, that excellent botanist and gardener, Robert Cross, to Central America to study the different species of Castilloas which could be recommended for transplantation to English colonies. The plants, which grew under the fostering care of Kew gardeners, did not survive in other places: they required the moist climate of their motherland, where it rains for nine months in the year.

Cross went again next year to bring young plants of the *Hevea brasiliensis* from the valley of the Amazon River to India. Although the Amazon natives guarded carefully and jealously the monopoly of their plants, Cross succeeded in bringing a number of Heveas to Kew. The result was the same as with Castilloas. The trees grow in the most divergent soil, but they flourish only and develop luxuriantly on the banks of a running stream, where the moisture is not swampy. On the Amazon ten days seldom pass without rain, and all plants are each morning enveloped in a mist. Only the south of Burmah offers a climate approximately similar to this. Another point also had not been considered sufficiently when the trials were thought of, and this had nothing to do with cultivating difficulties due to climatic conditions. A country intended for the rational cultivation of caoutchouc trees must be inhabitable in order to permit of a successful result. It must not only be possible to live in it, but the climate must enable the workers to put in a fair day's labour without bad results. The country chosen for the trials, a district in Assam, was as unsuitable as the home of the Castilloas and Heveas, the territories of the Amazon and the San Juan, in which only the "seringueiros" can enter during the dry season, and even then they are liable to catch the fever and to be so plagued by insects as to look forward eagerly to the end of the collecting season. These circumstances supplied the principal reasons for abandoning the idea of establishing a successful and rational culture of these two species of trees either in India or in America.

The results of the acclimatisation trials of the tree which supplies the Ceara caoutchouc, the *Manihot Glaziowii*, were more successful, as it requires a stony soil in a warm climate, and can stand a prolonged drought. Its home is in the mountainous districts of Brazil where a temperature of 75° to 85° F. is the average. The tree grows still better at a height of 1800 mètres (about 6000 feet) above sea-level; it requires no attention and adapts itself quite easily to the climatic conditions of the country of its adoption. The species can be cultivated on the Indian mainland and in Ceylon, and it is not without reason that the Manihot is called in this district the caoutchouc tree of the future. As the seed is protected by a very hard putamen the time of germination can be shortened by opening the putamen capsule with a file, otherwise the germination takes one year. The prepared seed is put into the ground in the open field and the first shoots show themselves in about three or four weeks. Another and better method than filing the capsule is soaking it in cold water, but in this case the germination takes longer and the first shoots do not show before three or four months. The young plants can also be grown from cuttings.

The caoutchouc from the Ceylon plantations is already on the London market, and it costs, according to demand and quality, from four to six shillings per kilogram. Experience has already shown that the Manihot can be tapped for the first time in its fifth year, and from that time it can be tapped twice annually, each time on three consecutive days. The Manihot plantation on the Cocowate station near Lunugalla, in Ceylon, which covers 80 acres of ground, and has well-developed trees, can be given as an example. During June and July the plants stop growing, the leaves begin to fall and seem to decay. But soon new buds and leaves appear. In the third year the trees have for the first time flowers and seeds, which, when they ripen, fall to the ground and soon show fresh germinations. At first the plants are still too young to supply much latex, each tree giving annually about 1 lb., but the production increases with time. If this figure is taken definitely for calculation, then one hectare (nearly $2\frac{1}{2}$ acres) supplies annually 375 kilograms = $7\frac{1}{2}$ cwt. of caoutchouc, representing an income of £75 when the lowest estimate of four shillings per kilogram is taken. A third of this amount, £25, is sufficient to cover the expenses, and two-thirds are thus net profit.

In other countries also, and especially in the French colonies,

trials of rational cultivation of caoutchouc trees have been made, as, for instance, on the French Congo. Here the native caoutchouc plant, the Landolphia, threatened to disappear, owing to the rapacious and senseless desire of the natives to get every drop of latex it contained. A French scientist, E. Pierre, the creator of the Botanical Gardens at Libreville, tried to avert disaster by the acclimatisation of foreign plants, and, for this purpose, he chose the Manihot, as was done for Ceylon. It appears as if the trial would be successful. Pierre writes about it to the following effect: "A single tree which I planted in October, 1887, has been the origin of 115 trees, the largest of which have already stems with 0.50 mètre circumference and are 7 to 8 feet high. The plant which M. de Brazza tried to introduce largely amongst the natives has a great future in the country. The tree imported in 1887 has already supplied 14,000 to 15,000 little plants, of which several thousand have been distributed to natives living in the remotest parts of the vast and hardly explored Congo territory."

The Director of the gardens at Libreville hopes shortly to be able to distribute another 200,000 young shoots for new plantations.

A young French colonist who has been living a few years in the Congo interior in N. Djole on the Ogoone, writes in a different strain: "The pahouins have received Manihot plants, and instructions for planting them have not been lacking, but most of the natives throw the young trees carelessly on one side when they are not watched. It is only necessary for them to go a little into the interior to find an easy and rich harvest; why, therefore, should they trouble about the work of planting and cultivating and waiting for years for the first yield, when the result falls probably to some one else? It is not sufficient to start new plantations, if the young trees are to be left in the hands of natives, unless these are under constant observation. The colonists must take the matter in hand, and closely guard the trees from undue interference. Only then will it be possible to show a good result after the time of probation has passed."

According to researches made by Paroisse, the Manihot plant at Libreville is not the same as the one cultivated at Ceara and in Ceylon, but a species which is native to one of the islands on the south coast.

In Cochin-China, where soil and climate are especially well

adapted for the acclimatisation of rubber plants, attempts to grow caoutchouc trees have also been made. The planting of the *Hevea guianensis* in the Botanical Gardens at Saigon has been successful, but whether this venture was as fortunate in its development as the one at Kew is not yet known. In Réunion trials were also made.

These notes are to-day a little antiquated, but they are worth mentioning with regard to the history of the development of caoutchouc productions and culture. The principal point of interest in connection with the above remarks is with regard to the *Kickxia africana* and its rational culture on the West Coast of Africa, especially in the Cameroon and the Congo districts.

As has already been stated, the Kickxia was not known as a possible caoutchouc-supplying plant before the year 1895, in the month of May of which year the caoutchouc export of Lagos which hitherto amounted to about 21,000 lbs., rose to ten times that quantity, and the total export of the year reached a figure over five million pounds, when it beame clear that a fresh source of caoutchouc had been found: and later on the Kickxia was discovered to be the fount. The caoutchouc came on the market under the name of silk rubber. Since that time many investigators have dealt with the plant, which has been found in many different places, according to Dr. Preuss also in the Cameroons. To-day it is known that the plant is indigenous to the whole coast of West Africa, from Sierra Leone to the Congo, and far back to the hinterland. It is now equally well known that the plant has long been known to the natives who frequently mixed its latex with that from the usual trees, causing frequent changes in different qualities and much head-shaking amongst those who tried to find the source of these variations.

Since Cameroon has become a German colony, all plants likely to prove useful are planted in the gardens at Victoria, where their nature is investigated. In this useful botanical institution the Kickxia has received much consideration amongst the caoutchouc-supplying plants.

Prosper Müllendorff, who in 1898-99 travelled on behalf of the *Cologne Gazette* to Togo and Cameroon, says in his report about this experimental agricultural station that it is not a botanical garden in the ordinary sense of the term, where plants are divided correctly after genus and groups, but that whole fields are devoted to one and the same plants, each one being

grown in large quantities, thus permitting a calculation as to their supply and productivity. After a few further remarks he states: "Our walk led us now to the caoutchouc plants, which are the most important in the Protectorate. The value of the caoutchouc export for 1897-98 was, according to the average purchase value of 2.67 marks in Cameroon, calculated for the whole colony as bringing in £55,000. But a rise must and will come, especially as the traders and merchants in the southern caoutchouc districts are eager to teach the natives the rational culture and collection, and to avoid the barbaric custom of draining all the latex from the lianas, which makes the trees become exhausted and die. Further north, on the Rio del Rey, in the territory of the German West African Trading Company, a caoutchouc planter has also begun operations, and as he can look back upon a prolonged successful experience in South America, it is certain that he will soon be able also to compete in the caoutchouc market here. We examined a Ceara caoutchouc tree (*Manihot Glaziowii*), which kind of tree has been profusely planted in the colony, and Dr. Preuss tapped the tree before our eyes. On the foot of the tree a leaf is inserted into the bark, over which the latex runs into the collecting vessel. A gully is cut with a gouge into the bark from the foot to a higher point, and the gully branches out at intervals. Soon the latex begins to flow, a part of it coagulating *en route*. Large trees, whose branches can also be worked, are climbed by the collectors with the aid of ropes. The wounds of a tree thus operated upon heal within six months, and we were shown trees which had been tapped a year previous but which had already sufficiently recovered to be tapped again. Similar experiments are made with the native lianas and Landolphias (of which seven kinds can be found in the gardens), to prove that by careful tapping the plants can be saved from destruction. Apart from the trees the lianas are of the greatest importance, because they can be planted in stony soil. Trials with Para trees have also been successful, and these trees have the further advantage of rapid growth, but they cannot be tapped before they are five or six years of age. A large number of them have already reached a good size, which serve also for the purpose of giving shade to the cocao trees. There are cuttings of a native Ficus tree and of other Ficus kinds. The *Ficus elastica* is represented, in addition to some from Assam which give a good supply of latex, only at stations of a high

elevation. A tree of this kind forms one of the decorations of the garden, and is remarkable for its wide-branching growth. Another tree, which has grown well, is from San Thomé, but, according to the manager of the garden, the tree of the greatest importance is one whose origin is still the quarrel of experts, which has recently been discovered on the Mungo River, the *Kickxia africana*. This has proved to be a caoutchouc-supplying tree of the first importance. The latex of the Ceara tree, when it has coagulated on the land, leaves, in addition to the little caoutchouc balls, a watery substance, but this latter is absent in the Kickxia latex, whereas the others have pear-shaped fruits. The Kickxia's fruit consists of two alternate pistils, oblong and round, standing at right angles, and about a span in width. . . . Great hopes are set on these trees, and as soon as the young plants are sufficiently grown to be properly and regularly tested, their nominal and industrial value will be definitely fixed. . . .

"The future of these trees in this country is therefore perfectly secured; the tree is to be found all along the coast at a low level, where it can easily be grown. The culture of the Kickxia offers great advantages, and should be taken up by capitalists, who will certainly miss a great opportunity if they leave the exploitation of this tree to other people."

The same traveller also visited the German colony Togo, and from his letters, as far as they concern caoutchouc, two passages are important and must be quoted. He writes: "The caoutchouc tree, *Manihot Glaziowii*, seems to have a great future. It is extensively planted and grows within one year to a height of 3½ to 5 feet. The tapping experiments have been successful, and resulted in an excellent product." And also: "It is a remarkable and an excellent testimonial for the natives that they are amenable to the influence of the Government and desist from killing the trees to get one supply of caoutchouc; in other parts of Africa these robbery methods still exist, and only too often the lianas are cut down at the roots and are at once rendered valueless."

Since then the botanist Rudolf Schlechter, during the years 1899-1900, has explored West Africa on behalf of the Colonial Economical Committee of Berlin. The reason for the journey was in connection with the conveyance of Kickxias and Ficus from Lagos, of root caoutchouc from the Lower Congo, and of Kickxias and Landolphias from the Upper Congo to Cameroon

with the intention of planting caoutchouc trees on a large scale. Schlechter took a large number of Ficus cuttings from Lagos, and between 30,000 and 40,000 Kickxia seeds to Victoria. The Ficus cuttings were supplied to the botanical garden and the Kickxia seeds were divided in the following way: 15,000 seeds were given to three interested cultivators and the rest to the botanical garden. About 99 per cent. of the seeds have germinated. From the Congo Schlechter took to Cameroon 400,000 Kickxia seeds, 1,000 fruits of a root caoutchouc, and about 250 seeds of a Landolphia kind which supplies an excellent caoutchouc.

At the request of the Geheimrath Wohltmann, Mr. Schlechter read a paper on the 3rd March, 1900, before the Society of Cameroon Planters at Victoria, briefly putting the collected facts of caoutchouc culture and the collection of latex, as far as these had any reference to Cameroon, before them. Considering the general interest taken in this question, the text of the paper is given in full, as it has been issued by the Colonial Economical Committee to all its members.

" . . . To begin with, it is necessary to consider the different kinds of caoutchouc plants with special consideration to their economical culture in the Cameroon colony.

"The Landolphias, the caoutchouc lianas, cannot be greatly recommended, as they supply only sufficient quantities when they have reached a considerable age. But where plantations exist the seeds should be collected and the little seedlings grown in seed beds should be planted round shade-giving trees, when they have grown to be four-leaved. On the other hand, seeds can be easily purchased on the markets of the Baguiris, where the Landolphia fruits are sold in great quantities under the designation of 'Manyongo.'

"The *Manihot Glaziowii*, the Ceara caoutchouc, are entitled to more consideration for the dry southern districts of our colony. The seeds, which should be slightly filed to provoke germination in a shorter time, are planted in places exposed to the sun and can then be left to look after themselves. Under such conditions as these (which are practically akin to wild growth) the Manihot can be tapped after five or six years. The quantity of the latex depends upon and varies with the different localities. The cultivation of Manihot is remunerative under all conditions, as the costs of planting, etc., are exceedingly small. The plantations of these trees can also be divided and

each division entrusted to a native to look after the collecting.

"The *Ficus elastica* gives in Cameroon, as far as can be judged, only an inferior product which exudes very easily and quickly. The product, which as flake-rubber is also collected from other Ficus kinds on the Gold Coast and in Lagos, varies in its price on the European market from 1.00 to 1.30 mark per kilo.

"The stems of the *Hevea brasiliensis*, the Para caoutchouc, which are to be found in the botanical gardens at Victoria, supply too little latex to make the caoutchouc tree one to be recommended for extended culture. Considering the Hevea has its home in the inundated districts of the Amazon River, where the stems are surrounded by water for months, it is hardly surprising to find that the results are different; and the cause rests mainly on the dryness of the soil to which they have been transplanted. It seems possible to me to make the cultivation of the tree successful and remunerative by planting it in inundated districts, on the banks of rivers, or in marshy soil.

"Of the *Castilloa elastica*, we have at present only small seedlings which will not become productive until after a few years; it is therefore impossible to give an opinion now as to the value of the cultivation. The seeds of these caoutchouc trees lose their vitality after a short time, and this adds to the difficulties of planting the Castilloa at the first.

"I will now speak of a caoutchouc tree which seems to be the most suitable for African cultivation, it is the *Kickxia elastica*. All of you gentlemen present have had the opportunity of noting how excellently the tree has grown in the Victorian cultivations. I have already made recommendations how to plant this tree in several places, but these shall be repeated here in brief.

"As soon as the little seedlings have six to eight leaves they must be taken from the seedbeds for transplantation. It is necessary for this purpose to clear the ground a little, *i.e.*, to cut down the undergrowth and the smaller trees. After this has been done the little seedlings can be planted at distances of five mètres (16-17 feet) from one another. It is sometimes necessary to thin out the plantation, until the Kickxias have increased in size. After two years they are sufficiently old to look after themselves, and after five or six years they are ready for the first tapping. In the Sango-Nganko regions I succeeded in getting two kilos of caoutchouc from one tapping, and

reached a height of ten to twelve feet and a circumference of eight inches. On another plantation, which Mr. Runge owns in partnership with Mr. Sholto Douglas, and on an outlying station belonging thereto, 27,000 *Ficus elastica*, 11,600 Heveas, besides 76 Castilloas, 48 *Manihot Glaziowii*, and 9 *Ficus Vogelii* had been planted. In Lunt the traveller saw a plantation belonging to Mr. Langbeen, where mainly Rambong (*Ficus elastica*) and Castilloas were cultivated. The plants stood the climate excellently, and grew satisfactorily. The seedlings are bought from the Battakers at four dollars per hundred, and as soon as they are one and a half feet high they are transplanted into their proper places. It is interesting to note that the Battakers put the Rambong seed in sandy soil on bamboo floats to keep them always equally moist, and also to protect them against their enemies, the ants and the caterpillars.

Schlechter does not say much of an excursion to British North Borneo, where the British North Borneo Company, in particular, carries on the caoutchouc trade, the production being small and the export hardly worth mentioning.

From Singapore, to which place he had returned, the explorer went to German New Guinea, where he first divided the caoutchouc and gutta-percha seedlings and seeds amongst the proper people and saw to their being planted in suitable places. The small beginnings of regular cultivation promise at the start a favourable development, and, in the opinion of Mr. Schlechter, the export of rubber from New Guinea, which is small at present, will soon increase. The samples which have been sent and placed before German rubber manufacturers and caoutchouc dealers for their opinion and judgment regarding the quality have been received with appreciation, and the value of the product has been fixed at five and six marks per kilo, one manufacturer even placing the value at seven marks.

In contrast with the strong and steady endeavour to place the cultivation of caoutchouc on a rational basis and to continue it on the proper lines, the news from the Congo State is all the more painful. When in 1876 the movement was started to explore and civilise Central Africa nobody spoke of business. The Berlin Conference of 1885 created the Congo State on the basis of free trade, and the new government of the State gave the assurance that it would neither trade directly nor indirectly. But after regulating, on 17th October, 1889, the right of trading between traders and natives, and restrict-

ing the trade in caoutchouc to a matter of exchanging goods, the State anounced, in July, 1890, that it possessed the right to trade in ivory on its own account. Soon followed further regulations, destined to make the ivory and caoutchouc trade a State monopoly, and it was not long before the State officials received instructions to concentrate their whole energy on the collection of caoutchouc, *as far as possible* without the application of force. The latter part of the order is very significant. How the caoutchouc production has been proceeding since then, Europe has learnt with amazement. It is not intended here to enter further into these scandalous reports, nor to fix the responsibility on the proper person, but it must be pointed out that all reports and eye-witnesses agree on the fact that the caoutchouc collection is conducted in a plundering, rapacious, and exhausting manner. Again and again public opinion has occupied itself with the scandal, and the subject has been fully discussed, for instance, in the Chambers of Commerce of Liverpool and Hamburg, the Society for the Protection of Natives, the German Colonial Society, and in the Press, especially in the English weekly paper *West Africa* and the *Cologne Gazette*. A short while ago the Governments exchanged notes on the subject, and it is to be hoped that the result will be successful in bringing the Congo State (which is probably the richest caoutchouc-producing land on the earth) in line with other countries, where the production is conducted in a rational manner for the benefit of all concerned.

The reports from South America are, on the whole, satisfactory: Peru, Colombia, Costa Rica, San Carlos, and the regions adjacent to the Amazon River are all striving for a rational management of caoutchouc production, and the results are satisfying the aspirations. It is deplorable that the uncertain political conditions of several South American States interfere frequently with the safe conduct of business. Drastic illustrations of this are of frequent occurrence, the whole of the Acre District being, at the time of writing, in a state of revolt.

III.—The Production of Raw Caoutchouc.

THE questions upon which the results of the annual rubber collection depend have already been stated, and one of these has a great influence on the quality of the caoutchouc. This is simply the care that the collector has taken with his work and the method which has been employed to separate the caoutchouc from the collected latex.

It has already been stated that the latex is collected by means of cuts made in the bark of the caoutchouc trees. This work may seem to the reader to be very simple, but still it requires a knack on which not only depends the momentary result, but also the future yield of the trees. An untimely tapping is against the fundamental rule which a sensible collector never loses sight of, *i.e.*, always to look out for an abundant and good yield, but with an eye to what is to be expected of the tree in future.

Two methods are recognised in obtaining the latex—

1. Cutting down the trees.
2. Tapping, by incisions in the bark.

Cutting down the trees leads to the quickest results, but it is irrational and barbarous; for the moment the yield is plentiful, and more abundant than by tapping the trees through cuts, but the tree is destroyed.

This method is plainly an unmethodical robbery, and cannot be too strongly condemned. The employment of this method can only be considered in two cases: (1) When plants are tapped which would wither or decay under any circumstances after the first operation, however careful the operator might be, and (2) when trees in a virgin forest have to be thinned out for some reason. The first reason, it is said, is upheld by the Gommeras of Peru, who state that this is the case with the *Hancornia speciosa*. According to their reports, insects attack the incisions of the trees and thus cause the decay of the plant. But if the stem is cut off above the ground, the stump soon sends up new shoots, which grow like bushes out of the old wood, so that after a few years a group of trees has grown out of the single stem. As the Hancornia is widely spread and the

collectors have always a sufficient number of trees for tapping, it has become an understood thing to cut down these trees, but only when the circumference is more than one mètre. There is at least some rationality in this method of collecting the latex. It is not quite clear (in view of the possibility of closing the openings in the tree stems by means of suitable materials, such as resin and other substances, which prevent insects from destroying the fibre) why these trees should die off in Peru, while they continue to exist and develop in Ceara, Ceylon, and at the Congo. With a little good will there could surely be found a way which would harmonise better with correct principles and forestry.

The second exceptional case is the clearing of virgin forests, and as long as the clearing process is conducted on a sound basis, it is perfectly right. Where such an abundance of vegetation exists, as for instance in the forests of Central Africa, that the collector cannot move in any direction, it is necessary to remove all obstacles to a proper working of the trees. Air and light are thus let in, and these take their share in the development of proper growth. In itself, this method is not irrational, but it depends upon the natives recognising the limits where the destruction must cease, and this is a point which it is difficult to make them understand.

Tapping the trees by incisions is a far more rational method, but care must be taken to prevent the trees from suffering damage; it must also be observed that the quality of the caoutchouc which has been supplied by the latex has not been impaired. It is universally recognised that Brazil, especially the territory on the Amazon and its tributaries, supplies the purest caoutchouc, and it was here that the method of tapping the trees was first employed. The method offers so many advantages, that everywhere where the conditions of the soil and the species of plants make it possible, it has been adopted, and the example of Brazil followed.

The most simple manner of tapping is the one formerly universally employed in Brazil and known as "arracho." It consists of running a rope round the Hevea slantingly with the knot at the higher end. Over this rope a number of cuts are inserted. The gushing sap runs first vertically down the stem, then follows the gully formed by the rope and the tree until it reaches the lowest point of the rope, where it runs over and is collected in a vessel suitably placed to collect it. Even this

method became dangerous to the trees as the seringueiros did not always take the trouble to remove the rope, and in this case the strangulated Heveas were hindered in their growth and very soon died. In its long spiral course the latex picked up too many impurities, such as moss, wooden splinters, insects, etc., which were later on, of course, found in the rubber. The cuts made by means of broad knives and sabres were often so deep as to wound the trees and destroy them. In many cases the cuts were not sufficiently deep and only a little latex was drawn, and this was mixed with other saps, which impaired the purity and especially the durability of the caoutchouc. For these reasons the method has been discarded.

The method of tapping now employed in the lower valley of the Amazon River is undoubtedly the most practical and best. It is described in all treatises on caoutchouc, and more or less elaborate articles about it have often appeared. The best descriptions have been given by Carrey and Chappel.

At dawn, about five o'clock in the morning, the seringueiro begins his work. If the estrada (about 100 to 150 Heveas) which he desires to rob of latex is far from the hut, he has already brought his tools to the spot. The tools consist of the machado, a small short-handled axe, with a blade of not more than three to five millimètres, a pail, and the "tigelinhas" or tin cups.

The seringueiro, or as he is called the "cauchero," is in most cases accompanied by his family or by one or more helpers. It is only very seldom that he works by himself.

After the stem of the tree has been properly cleared and the ground round about it has been swept, the tapping commences. With a single adroit stroke with the axe the bark is slit open just deep enough to extract the latex without damaging the tree. In this way every stem is slit open in about twelve places, care being taken that the axe does not go deeper than desired. The machado invented by the North Americans has proved very useful, and Carrey says quite rightly that this axe has saved more Heveas than all the Brazilian laws of protection put together. Since the collectors on the Amazon River have used this instrument, which makes only a slight opening that can easily be healed, all other tools (many of which had ruined innumerable Heveas) have disappeared.

Many collectors make the cuts in the shape of a V, others in curves about twenty centimètres (seven and a half inches)

distant from each other; others again are satisfied with simple vertical cuts, one underneath the other, from the height which they can reach with the hand down to the ground. The latter method can be recommended and should be universally introduced, as experience has shown that, while an irregularly and carelessly cut and tapped tree gives the proper quantities of latex in the first and second year, from the third year the yield diminishes until at last it becomes exhausted.

The repeated tapping does not affect the trees when it is properly managed. Heveas can be seen which are so covered with marks that not a patch the size of the hand can be found without a scar, and still they give their yield of latex. A tree of about 1.25 to 2.50 mètres (five to nine feet) in circumference on the lower part can stand twenty to thirty cuts every two or three days during the whole collecting season; a daily repeated tapping would exhaust the tree and not give a sufficiently large yield. The seringueiro divides his estrada of 150 trees generally into three sections, one of which he works each day. If the estrada is smaller, say of about 100 trees, two divisions are arranged. A total harvest consists of about twenty tappings for each year. If this limit is exceeded the yield of the next season would be seriously impaired. One man with his helpers is generally sufficient to thoroughly work one estrada, but it is difficult to state a fixed limit, as much depends on the industry of the individual collector and the respective distances of the trees.

The trees may be operated upon at any time of year, but the season usually chosen is from the end of August to the beginning of January, as the yield is less at other times. The work is commonly started at dawn, as the trees supply more latex when the night winds have refreshed them after a sweltering day. In several districts of caoutchouc-bearing land the seringueiros prefer to make the incisions at sunset and to collect the latex in the morning.

As already stated, the incisions extend as high as the collector can reach and right down to the ground, that is from about one foot above the ground to a height of seven feet. Under each of the cuts the seringueiro fixes, by means of clay, one of the tin cups in order to collect the latex. Each one of the incisions made at regular intervals drains the tree drop by drop of the latex until, within one to three hours, the yield is on the average about three centilitres. This quantity fluc-

tuates and depends on whether the tree is in full life or decaying. The yield, also, is not the same every year, continued drought or prolonged rains influencing the flow of the latex, this also depending on whether the cuts have been inserted on the sunny or the shady side of the tree. The reason why many of the Indians prefer the night time for the tapping process is that the rains following thunderstorms (which are of nearly daily occurrence and always influence the quality of the latex) never come by night, and this accounts for the collector's preference for night work. The natives also assure everybody that the yield is much greater at full moon than at any other time. How far that is true cannot be ascertained.

An estrada of 150 trees can yield at each tapping about 52 litres of latex, which gives generally 36 kilos—80 lbs.— of raw caoutchouc. Counting twenty tappings per annum, the yield amounts to 720 kilos (nearly 14½ cwts.) per collector.

On the Upper Amazon the tapping is arranged in a similar manner, but much less care is taken of the work, and the tools in use are more primitive. The farther the seringueiro penetrates the virgin forest, the less inclined he is to carry many and heavy implements. A bottle gourd or calabash serves as pail, a shell as tigelinha, and the small American axe is often supplanted by a broad crooked hatchet, the ruin and destruction of so many prospering caoutchouc trees.

Up to about ten years ago, the collecting of caoutchouc on the Amazon was almost solely in the hands of the natives who are domiciled there. Their work depended so much on contingencies that it was no wonder the quantities supplied were very irregular. The quantity collected was quite out of proportion to the possible yield. Conditions have improved since then, mainly owing to the increased demand and the higher prices paid for the material. The families of the natives (seringueiros), who formerly worked only by themselves and without outside help, have become owners of large districts (seringaes), and as their own labour was not sufficient for an exhaustive collection, men from the south were engaged as helpers. In this way many persons have been drawn to the work of collecting in the existing seringaes, and of opening up new districts and collecting centres. In former years the transactions between the collectors and the buyers at Para and Manaos were mainly conducted by a band of hawkers called ragataos. These people bought at Para and Manaos what they

thought suitable for the interior, such as foodstuffs, especially manioc flour, dried meat, and other preserves, cotton goods of all kinds, cheap jewellery, etc., and these collections they carried up the rivers in boats, where they exchanged the goods for caoutchouc. They generally returned to Manaos, after an eight to twelve months' journey, where the collected products were disposed of in the open market and to the best advantage. The steamships which now ply between all places on the Amazon River and its tributaries proved a deathblow to the hawkers, who have nearly all disappeared. The more convenient and more or less regular communication with the interior now permits the seringueiros to go down the rivers. When the collecting season is over, at the end of February or March, many seringueiros bring their caoutchouc to Manaos or Para, where they also purchase the necessary provisions and tools for the next campaign (safra). The seringueiro generally purchases his goods through an agent (aviador), who also undertakes the sale of the caoutchouc; the aviador acts as a commission agent in both directions—he purchases and imports the goods on his own account, and charges the customers the original prices plus commission. Some of the agencies have become of great importance, and Manaos and Para are the homes of a few houses whose connections extend to the whole interior. The larger houses have their own steamers, which visit regularly the Amazon and the branch rivers; they transport passengers and goods, generally only those connected with the business and interested in the customers. The steamers supply the seringueiros with the required goods and provisions, and on the return journey they bring the collected caoutchouc, which is sold on account to the seringueiro according to the ruling market price at Manaos or Para. Several English companies have started collecting rubber on their own account, but the results of these undertakings is still in doubt.

The method of tapping is, with the exception of a few slight alterations, the same in the whole of South America; the shape, length, and depth of the cuts and the mode of collection differ, but the principle remains the same.

The *Castilloa elastica*, which grows in Central America, requires a different treatment; the cut is not used, only a hole is pricked in the bark, which makes a smaller mark and does not need the use of so large and heavy a tool as the macheto.

Africa's methods of tapping are different in nearly every part of the continent, and until latterly the systems in use were impracticable and irrational. The African caoutchouc is not so good as the product from South America (especially such as comes from the Amazon), and it loses still more in value in its preparation. When the cuts are too deep the sap mixes with the latex, and the caoutchouc is deteriorated in consequence.

In Asia and where the caoutchouc is collected from the different Ficus species, the cuts are to the depth of the liber, and in elliptic shape, on the lower part of the stem and the aerial

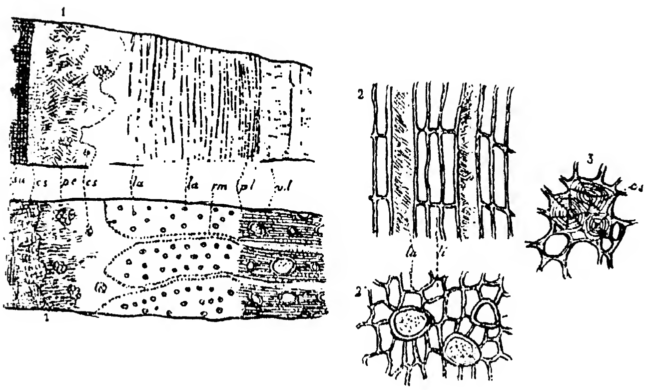


FIG. 8.

1, 1^1, Longitudinal and transverse section of the *Urceola elastica*: p.c. bark parenchym, c.s. hardened cells, lm. milky veins, r.m. radiation of marks, p.l. wood parenchym, v.l. large veins filled with latex.

2, 2^1, Longitudinal and transverse section of the milk veins in the bark of the *Urceola elastica*: la. milk veins, li. liber.

3 View of the hardened cells of the *Urceola elastica*: c.s. hardened cells.

roots. The quantity of latex depends on the season; in February and March only a little can be collected, but the quantity of the caoutchouc is at this time much larger, for which reason these are really the best months of the season. The same thing occurs during the month of August, when the caoutchouc amounts to 30 per cent. of the contents of the latex, whereas during the other months the average is only 10 per cent.

Australia has partly adopted the Asiatic example, especially as far as the same species of plants are concerned, but cruder methods are also in use, particularly where the indifference and shortsighted neglect of the authorities permit the natives to do

what they like. The *Urceola elastica* is one of the greatest victims of this thoughtless destruction, this tree reaching in other countries the diameter of the average man. The stem of this liana is cut to pieces, and these are held over vessels which receive the latex. When the latex begins to issue slowly, a faggot fire is lighted to help the flow. The methodical collection in these cases, especially for the *Urceola esculente*, should be the cutting of incisions in the shape of a V, from $\frac{1}{3}$ to $\frac{2}{3}$ inch long and $1\frac{1}{4}$ to $1\frac{1}{2}$ inch deep. The cuts go through the bark and reach the wood. A microscopic inspection of a section of the bark proves the necessity of such a procedure. Under the cork-like growth (see Fig. 8, *su*) which forms the upper part of the bark is a thick, hardened layer (*c.s.*) of about twelve radiating rows of cells; secondly, a strongly developed soft, spongy cellular tissue (*p.c.*), which has on some parts accretions of hardened cells (*c.s.*), and, thirdly, a very soft thick inner bark (*li*), which forms, of itself, half the diameter of the bark, and is, especially in the younger parts, very rich in milky veins. The cuts must reach the "cambium" in order to approach the milk veins, for only then can the process be satisfactory.

In brief, these are all the methods employed for the collection of latex. It is self-evident that rational production is of the greatest importance to the life of the plants, just as the quantity of latex produced and the residue of caoutchouc depends on the methods of production and collection. The carefully tapped caoutchouc has a great advantage over the other, and its durability as a raw product is vastly improved by proper treatment. A too deep and wide cut, which lays bare the liber, causes the admixture of other saps, and these render impure the oozing latex and alter its chemical character. This circumstance becomes of still greater importance in the cases where the latex is collected from the felled trees, where the mixing with other saps is naturally much larger. The addition often consists of sugar, starch, resins, albumen or tannin, all of which have a deteriorating effect on the quality of the caoutchouc. When the production of raw caoutchouc comes under consideration, of which more in the following chapter, an opportunity will be given to consider this point a little closer.

The preparation of raw caoutchouc is one of the most important and at the same time one of the most interesting points of the whole caoutchouc industry. Most writers who have dealt with this subject acknowledge the effect of the process of

preparation on the quality of the product, which thus influences and restricts the applicability of caoutchouc. Too often the evil is mentioned, but no way is pointed out how to improve the methods. This improvement would not only influence our industry and our trade, but it would be of far-reaching importance as regards the development of all tropical colonies; French Guiana contains for instance an enormous number of Heveas, as well as of other caoutchouc trees, which can supply an excellent material. The climate is the same as on the Amazon, but although French explorers like Coudreau have again and again drawn attention to Guiana caoutchouc it has hardly become known in the trade; the little the colony supplies is to a great extent mixed with Para, and the quality thus obtained is equal to Para in every way.

The French colonies on the Senegal, in the Soudan, Congo, on the South River, in Nassi-Be, Réunion, Madagascar, and the interior of Africa, also in Cochin-China, Assam, Tonkin, and Australasia have an abundance of caoutchouc-producing plants whose product can be favourably compared with those from usual sources of supply. This natural abundance, however, is only in a few cases and in a small measure made use of, partly because nobody gives the movement the proper backing, also because the required guidance and enterprise are lacking, but more especially because the methods adopted are not the right ones, or in many cases unsuitable for the plants to which they are applied. The result is a yield which is merely nominal compared with what it should be. In a small handbook, "Caoutchouc and Gutta-percha at the World's Exhibition, 1889," René Bobet wrote as follows on the subject:—

"The samples which come from the Mayotte, Nassi-Be, and from Senegal are of medium quality; the exhibited products from Dinan Salifou, on the other hand, are excellent. The products from Madagascar are middling and soft, and those from Réunion moderate. To improve them would not be difficult; it would only require a little more care when the material is being dried. Several kinds of caoutchouc from Madagascar are firm, strong, and altogether of the best quality. The caoutchouc supplied from Gabon, Assinia, and the French Congo is very sticky; the only exceptions are the balls from Casamanza and the flat pieces from Assinia. These species prove that these countries could supply good material if a little care was taken in collecting. It depends on the improvements made in the

coagulation process. To do this it is necessary to know exactly the nature and properties of the latex, also the different coagulating methods from which the true method has to be developed. As it has to be taken for granted that these researches cannot be made on the spot, the authorities of the colonies should give orders to have them made in Europe, for which purpose they would have to supply the following samples and details :—

"(1) A sample of caoutchouc produced according to the method in use. A detailed description of the method would be desirable.

"(2) A certain quantity of latex, in exactly the condition it flows from the tree when the cut is made. To prevent any changes in the latex during the transport, a little ammonia should be added, and the mixture sent in hermetically sealed bottles.

"(3) Notes of the name and species of the plant, also a description of leaves, flowers, fruit, and seeds. The season when the latex has been collected must be stated.

"On this information it would be possible to define the treatment to be observed when collecting the latex, also which method would be most suitable when coagulating the material. If the colonial authorities took care that the results of the researches became known to all, the natives and the colonies themselves would be greatly benefited, as it would be possible to give certain kinds of caoutchouc a much higher value than they possess to-day. Central Africa would be much interested, as the enormous wealth of caoutchouc trees would greatly influence the extensive development of the caoutchouc trade, always provided the caoutchouc is of good quality. The demand for African caoutchouc would advance, and the buyers on the coast would be able to pay higher prices, which would have the effect of spurring the natives on to greater exertion."

These recommendations ought to be carried out, as if undertaken they would undoubtedly prove of great importance in the improving of the quality of raw caoutchouc. The best methods are naturally those in use where the caoutchouc is gathered from trees which have been planted regularly. The trees are properly attended to, the gathering is regular and periodical, and the collected latex is kept clean and free from foreign substances.

The latex produced by tapping or cutting down of plants separates the caoutchouc only when a certain coagulating

method is employed. These methods change from country to country, from province to province, and even differ on the banks of the same river. It is therefore not a rare occurrence to receive caoutchouc from the same country and trees which is very different in quality, this result being due to the method of coagulating the latex which has been employed. James Collins, an Englishman, and Dr. E. von Hoehnel, a German, have noted the various methods of coagulating the latex and the systems used for the production of raw caoutchouc in the different countries. The following table gives a clear view of the different methods and where they are employed. A description of every method follows this table and will be useful.

The Coagulation of the Latex.

This is brought about :—

I. By heat—	
(1) By artificial heat—	
(*a*) Dry heat or smoking .	On the Amazon, in New Caledonia.
(*b*) Moist heat . .	In Mexico, Central America.
(2) By natural heat—	
(*a*) Separation by the Soil .	In Angola.
(*b*) Separation by the human body . .	In Congo, Angola.
(*c*) Evaporation on level ground . . .	In Ceara, Angola.
II. By skimming—	
(3) Skimming after doubling the bulk of the fluid by addition of water .	In Bahia.
(4) Skimming after a rest; addition of four or five parts water, draining, washing, and pressing	In Bahia, Congo.
III. By decomposition—	
(5) Chemical decomposition by mineral reagents .	In Matto Grosso, Pernambuco, Maranhao.
(6) Chemical decomposition by vegetables or plants employed as reagents .	In Peru, Guatemala, Nicaragua, Gambia, Madagascar, Casamanza.

IV. By natural and artificial heat combined with chemical decomposition	In Gambia, Senegal, Mozambique.

V. By heating.

This last-mentioned method was discovered by R. Rousseau, but has hardly as yet been tried on a large scale. Since, however, it has been known that caoutchouc could be obtained from the roots of species of Clitandra and Carpodinus, the method has become general in dealing with these roots.

I. 1 a.—Coagulation by Means of Artificial and Dry Heat or Smoking.

This method, especially suitable for the Heveas and Micrandas, is mainly in use for the preparation of Para rubber on the Amazon; this is the method of the production of caoutchouc known and valued above all other sorts for its purity, elasticity, and durability. The same process is also employed in other parts of Brazil, and has been adopted in Venezuela and Guiana. It can be described without hesitation as the best of all known methods, and it is well worthy of a more exhaustive description.

The collector, or his helper, takes the cups one after the other carefully from the tapped tree and empties them into a vessel, a pail, or a large gourd bottle, which is held by a wide-meshed net and has a twisted rope as a handle. The emptied cups are replaced in the same positions where they were taken from. Each cut is inspected, and frequently the incision, which may have become closed through the coagulation of the latex, has to be re-opened. The thin skin, which has already coagulated through the natural heat, falls off and is carefully placed on one side. The latex of two or three trees fills the pail. In the event of the hut of the seringueiros being close to the estrada, the whole collection is without any precaution placed in a large tank; if the seringueiro is a long way from his hut, the latex is mixed with 3 per cent. of ammonia, which prevents the coagulation in the meantime. It is only when the whole work of collecting has been done that the real preparation of the caoutchouc, the smoking, begins. For this purpose the workman places the smoking apparatus, the so-called "fumeiro," in a fire-place which has been scooped out of the ground and whch has been carefully cleaned. The "fumeiro" is a kind of oven of baked earth, with at the top a cone-shaped tube of small diameter, so as to prevent the spreading of the

smoke. A faggot fire is now lit on the fireplace, and as soon as the smoke is sufficiently thick, palm nuts are added, the Indian testing the thickness of the smoke with his hand. The nuts used for the purpose are the fruit of the Urucury, or the Nauassu palm (*Attalea excelsa* and *Manicaria saxifera*), which are always found in the neighbourhood. In case these fruits are not to hand, those of the *Maximiliana regia* are substituted. The use of nuts to accelerate the production of smoke is only recognised on the Lower Amazon, where the best caoutchouc is produced. In all other places the smoke of the faggots is considered sufficient.

As soon as sufficient smoke has developed the cauchero takes the so-called form or palette, a wooden instrument with a handle, three to six feet long, which is not unlike the beater used in many districts by washerwomen. For a moment the workman holds the broad flat end of this form over the smoke, or in clay water, then he dips it in the pail of latex, and after it has been dripping off he holds it again over the fire, so that both sides of the palette are equally exposed to the smoke. The thin layer of latex which sticks to the form coagulates under the influence of the heat, the water evaporates, and the first thin layer of caoutchouc is ready. If the latex has coagulated uniformly, the form is again dipped in the pail and the first process is repeated until the caoutchouc has become sufficiently thick.

A method which differs only slightly from this, makes use of a form with two handle-like connections, and in this case the form is not dipped into the latex, but the latex is poured over it. On the Lower Amazon the usual form of the raw caoutchouc is loaf-shaped and weighs about eleven pounds. This thin coat is cut open with a knife which has been dipped in water and the form taken out, when a new block of caoutchouc is begun. A workman can make from four to five pounds of caoutchouc by these means within the hour. These rubber loaves are known in the trade as "biscuits." The biscuits are still moist when they come from the forms, and must be dried for several days in the sun. They are then spiked on two running parallel poles, and sent to the trading centres. The trade knows this material as "fine Para biscuits."

Fine Para used to come upon the market also in various man or animal-like shapes, which must have tried the artistic capacity of the collectors. These fanciful shapes, however,

are infrequent nowadays, and can only be seen in museums, or in factories where they are kept as curios.

The difficulty of this method of coagulation is doubtless the smoking, but the world-wide renown of the Para rubber, preferred on all markets and in all factories, is undoubtedly due to the process as a whole.

To recognise fully the usefulness of the method above described, the composition of the fresh latex must be taken into account. The latex of the Heveas and the Micrandas, of which the Para rubber is made, contains—

32	per cent.	caoutchouc.
12	,,	organic matter (of decomposing properties).
55 to 56	,,	water.
up to 3	,,	ammonia (added).
		traces of resin.

No other latex has such valuable properties as this, but when one takes into consideration the care that is taken in collecting the fluid, and the precautions that are used in preparing it so as to avoid loss by evaporation of the water and to destroy on the other hand the decomposing and fermenting substances, then it becomes clear that the excellent quality owes nearly as much to the method of preparation as to the exceptional properties of the latex.

The presence of substances in the latex which decompose and ferment is a condition which can become very dangerous to the caoutchouc. To prevent this the natives have, instinctively and without any scientific knowledge, adopted the simplest means. The repeated influence of a low heat removes first the greater part of the water, when coagulation becomes momentarily possible; but the imperfect combustion of the wood also produces carbon, an excellent antiseptic, to which the favourable results obtained by this method in Brazil must be ascribed. The combustion also evolves creosote and ammoniacal gases, which, mixing with the smoke, have also an antiseptic effect. The influence of the palm nuts in this direction has not yet been determined, but as they produce a denser smoke, it is clear that the antiseptic effect is also increased.

The repeatedly applied heat, influencing each time only a small quantity, and improving it by the removal of the water, has also another result. By this method the forming of air bubbles is prevented, and small quantities of uncoagulated latex

cannot adhere to the other caoutchouc, which otherwise would set up fermentation on account of their nitrogenous properties.

In addition to what has been stated, it may be permissible to give an account of another method (which can only be described as an imitation of the coagulation method used on the Amazon), used by Grandjean and Waser in New Caledonia and in the Loyalty Isles, and which has given the best results.

In his work on the colonisation of the New Hebrides (Paris, 1895), Dr. Daville speaks of this method as follows:—

"The tapping is very simple. In addition to the Brazilian tigelinhas another tool is needed. This has a cone-shaped gully, which ends in a hollow triangle and has on one end a sharp edge, on the other a hook. The edge serves for insertion in the bark and to cut the opening for the latex. The oozing milk runs through the gully to a tin cup hanging on the hook; these cups hold about 10 to 15 centilitres. It is easy for the workman to hang the cups on in the morning and to empty them after three or four hours into a pail, a bottle, or a tin can, when the cups can be quickly replaced."

Otherwise the method is the same as described. An exceptionally fine and valuable caoutchouc has been the result.

It is only necessary now to give a few details about the production of the less fine Para rubbers; these are the Para grossa, Para entrefina, and sernamby or negroheads.

The residue of the caoutchouc which sticks to the opening of the cuts or remains in the tigelinhas gives the material for a second quality of caoutchouc; these remnants are collected and formed into flat balls. From time to time each ball is dipped into fresh latex, and after every one of these coverings it is smoked like "fine Para." Several layers of fresh latex make the upper portion of the biscuit, and the rubber has the external appearance of the best Para. A cut with the knife is sufficient to reveal the delusion. It can at once be seen that it is a similar, but not the same nor an equally valuable product. The caoutchouc contains a much larger proportion of water, the nitrogenous matter is also greater and fermentation and decomposition is not quite avoided, the main reason for this being the coagulation of the latex due to natural heat only. The coagulating method will be described later, when the serious drawbacks of the method and the reason for the inferior quality of Para entrefina will become quite obvious.

All the remaining portions of the fine Para and the Para

entrefina, as well as the scrapings from the forms, the residue in pails and tanks, etc., are worked into blocks and packed in boxes or barrels. The whole sticks together and takes the shape of the receptacle. This inferior quantity is named sernamby or negroheads. It is moist, contains much uncoagulated latex, even parts of plants and animals, and it has never undergone the necessary antiseptic process.

I. 1 b.—The Coagulation of Latex by Means of Moist Heat or Boiling.

This is a very primitive method which is employed by the Indians in Mexico to coagulate the latex of the Castilloa trees. The latex, which is tapped by means of cuts or pricks and collected in a piece of bark or in a pot, is passed through a sieve into a boiler, under which a faggot fire is lit. As in the case of animal milk, the cream collects on the top, and, after boiling for a while, it becomes firm and separates itself from the watery portions of the latex. By these means caoutchouc slabs are obtained which are dried and pressed to free them from the moisture before they come on the market.

It is clear that this method has many grave defects. The material cannot be boiled sufficiently long to destroy all the substances which cause fermentation and decomposition. Pressing is not sufficient to remove the moisture, and in spite of the sieving, the treatment of the latex has not been sufficient to remove all traces of vegetable and mineral impurities. Experience and results have shown that this contention is correct. Examination of the caoutchouc slabs, which are produced by means of boiling the latex, shows the formation of air bubbles in the black-looking rubber, and these bubbles are filled with a thick green fluid in which sand and wooden splinters are to be found. In latter years Mexico has supplied another rubber from the latex of the Castilloa, which, contrary to the first mentioned, is light brown and fragrant. It contains neither sand nor other impurities. It is nearly as elastic as Brazil caoutchouc, and the loss on washing it amounts only to 12 to 15 per cent. By what means the new caoutchouc has been produced is still unknown, but it is surmised that a quantity of sea salt has been added to the latex. The boiling of the latex is also the method employed in British India, and the preparation of the latex from the Ficus which gives the Assam caoutchouc, is done by the same means. Mention must here also be made of

the preparing of the so-called root caoutchouc as employed where the Carpodinus and Clitandra species are found, out of whose roots the product is procured. The method is employed in the Congo and in the hinterlands. According to Dr. Warburg ("Die Kautschukpflanzen und ihre Kultur," Berlin, 1900), the method consists in cutting the roots into pieces of eight inches in length, which pieces are put into bundles and exposed to the sun for five or six days. They are then placed for ten days in water and are beaten with wooden sticks, after which they are boiled and again beaten with wooden instruments. The product, which comes on the market in finger-thick squares, is naturally of inferior value, and even if 30 to 50 per cent. foreign substances can be eliminated when the material comes to Europe, the freight has to be paid for the whole. It is also very probable that the acids which are created by decomposition have a deteriorating influence and make the caoutchouc resinous. To clean the product properly trials have been made with cylindrical cleaners, one of which was sent for the purpose to Popocabaca. Warburg is of opinion that in connection with the mechanical treatment, but in addition thereto, a treatment with alkali or bisulphide of carbon, which would prevent the decomposition, would find better results. Contrasted with the desire to make the caoutchouc of the Carpodinians and Clitandras a useful product, the method mentioned by Dr. Rob. Henriques ("Der Kautschuk und seine Quellen," Dresden, 1899) can only be described as barbaric and can only lead to open fraud. The natives pound the roots in a mortar, boil the substance and form it into bells, which they often cover with spun caoutchouc thread to hide the enclosed kernel. This method is strictly prohibited in German and Portuguese colonies.

I. 2 a.—The Coagulation of Latex by Natural Heat. The Soil as a Means of separating the Water.

Coagulation by natural heat is mainly used in East Africa. This does not mean that the process is not in vogue elsewhere, but it seems that all the primitive methods, which are the cause of the inferior quality and the low price, are peculiar to Africans, whose laziness is only surpassed by their greediness.

Several tribes on the Congo and in Angola producing rubber mainly from Landolphias, gather the product by the following method :—

The negro taps the tree regardless of the effect of the cutting, which can easily cause decay. The latex flows on the ground which is not even cleaned for the purpose. The hot air absorbs the water of the latex, and when this drips on the ground the coagulation is already half completed. The hot and dry soil absorbs the rest of the fluid, and the negro's work consists only in the picking up of the material.

It is hardly necessary to criticise such a primitive method; but worse remains, for, instead of at least cleaning the caoutchouc from the mineral impurities, the native adds wilfully to them. The soil, which acts in this case as a filter, can only absorb the fluid from the external part of the latex, as a skin is soon formed which covers the material and prevents the outlet of the water. Owing to this, the inner material retains nitrogenous matter, sugar, resin, etc., the caoutchouc is soft and sticky and smells abominably, the smell making itself still more obnoxious later on. The loss on washing the material in a factory is very considerable.

I. 2 b.—Coagulation by Natural Heat. Evaporation on the Human Body.

This highly original method is also in vogue amongst the East African natives, and is certainly preferable to the last-mentioned plan. According to R. V. Merlon, the Congo collectors deal with the latex in the following manner: The negro, when tapping the lianas, collects the latex in the hollow of his hands. As soon as sufficient has been accumulated, he smears the material over his body, and in this curious covering he returns to his hut. The latex soon dries up and becomes flaky, when it is torn off in shreds and rolled in balls.

Dr. Welwitsch states that several Angola tribes use the same method. These natives press their hands underneath the cut against the plant and let the latex run over their arms. As soon as the cover is sufficiently thick the caoutchouc is taken off like a glove, beginning with the removal at the elbow.

Although this method cannot be recommended, as it does not destroy the matter causing fermentation, it has at least the advantage of preventing the mixing of foreign bodies with the latex. As the coagulation takes place in thin layers and over a large surface, the evaporation of the watery contents of the latex by the heat of the human body is almost perfect.

I. 2 c.—Coagulation by Natural Heat; on other Flat Bodies but not the Soil.

Brazil is the home of this method, which is used for making Ceara caoutchouc (Ceara scraps) out of the *Manihot Glaziowii* latex. But the process is also known in West Africa and India.

In Ceara it is worked in the following way: The tree is tapped when three years old, and when the stem has attained a diameter of about five inches. When the seringueiro has cleared the ground round the tree he covers it with banana leaves to collect the dripping latex. Cuts are then made from the bottom to about six feet high on different points and in all directions. The latex of the Manihot is much thicker than that of the Heveas and Castilloas, it runs very slowly and only infrequently flows to the ground. The greater part of the latex coagulates on the bark of the tree and remains hanging there like the gum on our trees at home. To allow it to become sufficiently dry it is left several days on the tree and is then taken down in strips and rolled in balls, in which form it comes on the market as Ceara scraps.

The caoutchouc collected at the beginning of the season is light in colour and is of the best quality; the second quality is darker brown and is collected when the rainy season has started. The caoutchouc collected on the foot of the tree gives a third quality, which is often accidentally, often intentionally, largely mixed with sand and soil. The loss on washing and working is often more than 50 per cent.

It is not to be wondered at that caoutchouc produced in this way contains a quantity of mineral and vegetable materials, which detract much from its value. The Ceara caoutchouc has a fine amber colour and is nearly transparent. It becomes opaque and white when it is stretched to some extent. These remarkable properties, which Morellet did not find in any other caoutchouc, are caused by numerous little holes in the interior of the material by which the light rays are broken.

Ceara caoutchouc has a fairly strong smell, which becomes obnoxious when the rubber is exposed to moist heat. If clean and pure the loss on washing is 20 to 25 per cent., and the rubber is possessed of much strength. There would be a much greater demand if it was more carefully prepared and not so much mixed with earth and other substances.

The latex of the Manihot is, in quality at least, equal to that of the Hevea. It is even superior, as the quantity of nitro-

genous and other matters causing fermentation is smaller and it contains less water. But still after working the result is only 75 or 80 per cent. of pure caoutchouc. The difficulty in storing Ceara scraps is also a disadvantage, as they require a cold and dry storage on account of the danger of fermentation. In spite of these drawbacks the rubber from the latex of the Manihot (whose thickness makes the working more difficult than that of the Hevea) could be improved by a more suitable treatment. Instead of letting the latex run down the tree, it should be collected in cups and at once mixed with a weak solution of alkali. When quite fresh the latex mixes easily with water, especially if this contains alkali. It would be possible thus to keep the latex fluid until it could be properly coagulated by smoking. This is a simple and easily accomplished method to obviate the disadvantages of the Ceara caoutchouc and to heighten its value. The trials which have been made with this method produced excellent results and shewed the advisability of introducing it. Unfortunately the natives do not wish to learn, preferring their ancient, quicker, and easier process of production.

The Manihot which grows on the granite rocks in Brazil supplies a small quantity only of the thick latex; but the tree can grow also in the valley and in moist soil. The latex then becomes thinner and more plentiful, and it is easier to employ the above recommended treatment. It would be interesting to test the coagulation of this latex by natural heat and with the addition of ordinary salt recommended above. The best results have hitherto been reported by using the method. It should not be forgotten that the caoutchouc is much improved by compressing the blocks and balls, the drying becoming more complete.

It must finally be stated that the Manihot in the province of Ceara does not supply a uniform latex in every district. Whether this is caused by climatic conditions or a degeneration of the plants is an open question. It is true, at any rate, that in some parts the Manihot does not repay tapping. The tapped tree gives a few drops and then the flow ceases. This sterility is not real, for if the cut is inserted at the foot of the tree near the root tubers, the latex oozes out in satisfactory quantities. The native uses this latex for the production of the so-called "sernamby." The preparation is so carelessly done and the material so much mixed with sand and stones, that it is hardly of any use although it has the same properties as the Ceara

caoutchouc. It would not be difficult to dig a groove round the tree before tapping and to line this with moist clay, which would dry to a hard surface. The prepared ground would easily absorb the water of the latex, and the result would be a rubber as good and clean as is supplied from the plateau.

II. 3.—Coagulation by skimming after the Addition of an Equal Quantity of Water and a Longer or Shorter Rest.

The latex of the Hancornia is treated by this method of coagulation. It is used also in Bahia, in several places near Nicaragua, in Central America, for the Castilloa, and in Assam, where the latex of the Ficus is thus prepared.

In Bahia, the mixed latex and water are allowed to remain quiescent for a certain time. Two strata are soon formed, of which the upper layer is like butter. As soon as this stratum has reached the required density, it is taken off, dried, and sent to the market.

The natives of Assam put the caoutchouc which has been prepared by this method in pots over a small fire to accelerate the drying. To remove the superfluous water and close the pores of the caoutchouc the Central American collectors roll them with wooden rollers and expose them for a final drying for a fortnight to the sun, when the material is ready for the market. These three methods of production are primitive and can only provide a caoutchouc of inferior quality. The loss in washing amounts frequently to 50 per cent., especially when the material is fresh. This coagulation method separates not only the water but also a certain quantity of uncoagulated latex, which can easily be proved by a microscope analysis, or still more simply by pressing a drop between the thumb and forefinger. The warmth of the finger causes coagulation, so that when the fingers are separated the caoutchouc can be seen in elastic threads (Morellet). The unpopularity of the product will be understood, although the caoutchouc itself is as strong and elastic as others.

II. 4.—Coagulation by Resting, after adding Four to Five Times the Quantity of Water.

R. P. Merlon has described the process which is often used for coagulating the latex of the Landolphias on the Congo. Cuts which go through the bark of the tree are made with a sharp instrument, but these must not reach the heart, as other-

wise a second latex is tapped which is watery and corrosive and spoils the whole fluid. The incisions are either vertical or sloping, and always one above another. Under the lowermost a broad bent leaf is fixed by means of caoutchouc or clay, which collects the latex and guides it to a gourd bottle fastened at the bottom of the tree. The bottle has an opening at the bottom which is closed at first. The latex is very fluid when oozing and looks like animal milk which has been thickened by boiling for a long time. When still quite fresh the latex is mixed with four to five times its quantity of water, and this addition accelerates the coagulation. The caoutchouc separates and becomes like cream on the surface. After twenty-four hours the cork is taken out of the opening at the bottom of the bottle, and the water and a large part of the organic matters liable to cause fermentation are run off. The caoutchouc is retained as a semi-fluid material which then undergoes a final coagulation in a wooden vessel, in which it is exposed to the sun for a few hours. The caoutchouc has now thickened, but it is not yet sufficiently compact and requires to be kneaded. The lower portion has frequently become hard when this stage is reached, for which reason it is cut up in small squares or thimbles, which shape has given the name "thimbles" in the trade. The caoutchouc thus produced has, like the aforementioned, the drawback of containing too much water and nitrogenous matter, in addition to uncoagulated latex. The fermentation soon makes itself felt by its characteristic and obnoxious smell. To prevent this, the material is sometimes washed, but never sufficiently, and the product is spongy with many holes, which contain a sticky fluid causing the just-mentioned smell. The loss in washing is very large, being as great as 30 to 40 per cent. at times.

Other kinds of caoutchouc are made out of the latex of the same Landolphias, which do not show the same disadvantages. This proves the contention that it is the irrational treatment of the latex, and the method only, that is the cause of the small value of the product.

III. 5.—Chemical Decomposition by means of Inorganic Agents.

This is a speedy, easy process, and it will cause no astonishment to hear that it has spread quickly in America and Africa. Pernambuco, Maranhao, and several other caoutchouc qualities of the Ivory Coast are produced by this method.

1. *Coagulating with Alum.*—This method for treating the Hancornia latex bears the name of its inventor, Heinrich Anton Strauss. If a solution of common alum is added to the latex, coagulation at once takes place. The material is spread on hurdles to drip off for eight days, when it is cut to pieces and dried for another month in the sun before it comes on the market.

According to Morellet, the Strauss method is very simple, but the results are not satisfactory, and the enthusiasm with which J. Collins recommends it has no foundation. He says : "This method, which has been purchased by the Government of Pernambuco, is excellent, as it does not require to be used when the latex is collected and further coagulation is a cold process."

The caoutchouc which has been produced by this method deteriorates in time, and when it becomes old it has very little market value. The elasticity of such a piece of caoutchouc is soon lost, and it becomes as hard as cardboard and unfit for mechanical working. It becomes granulous and brittle, the alum blooming and crystallising on the surface. If the inside and outside rose-coloured rubber is cut open, numerous holes can be found, which not only contain uncoagulated latex, but also alum water, neither of which has had time to escape during the rapid process. A part of the alum water could be removed by pressing, but the collector cannot carry a pressing apparatus in his outfit, besides, the drying would still be insufficient, not to speak of the evil effects of the alum. The method recommends itself by its cheapness and saving of wages, but the product suffers and the costs for transport run high on account of the 60 per cent. loss in washing.

The coagulation with alum has no great future. The manufacturers have recognised the bad qualities of the product and refuse to take it.

2. *Coagulating by means of Sulphuric Acid and Sea Salt.*—In Maranhao and Matto Grosso sulphuric acid takes the place of the alum. Sulphuric acid has, like all other acids, the property of causing a very rapid coagulation. This change takes place so quickly that sufficient evaporation of water cannot be assured, to which disadvantage must be added the unantiseptic influence of acids, thus leaving the before-mentioned evil results still existent.

The coagulation can also be produced by a solution of sea

salt. Salt offers no transport difficulties, its antiseptic influence is known, and the salt has therefore been adopted in the two provinces which formerly used the acids. Several African caoutchoucs, such as those from the Ivory Coast, Cameroon, and the Congo, are very much like the American caoutchoucs here mentioned, and, like these, they owe their preparation to the treatment with salt water.

3. *Coagulation with Soap Suds.*—This very curious method, which is used in Peru for treating the Hancornia latex, may be placed between the decomposition with minerals and the coagulation with vegetables. E. Bard writes about it as follows : " To coagulate the latex it is poured into a wooden pail, or holes in the ground, which hold about 65 pounds of the fluid. A quarter of a pound of soap (or rather more) is dissolved in a pail of water. Two pails of the solution are sufficient for 65 pounds latex. The two fluids are poured together into one tank and beaten by hand to facilitate the coagulation. The caoutchouc comes out in the form of a block. To drain the water contained in it, it is cut open everywhere with a knife, but the cuts are seldom deep, as the caoutchouc otherwise loses in weight."

This caoutchouc is naturally very porous and contains much water; the primitive methods permit also the easy admixture with foreign substances. The influence of the soap is not quite clear; the addition of water, as in other methods, helps the coagulation by making the latex more fluid and facilitating the separation of the little caoutchouc globules from the liquid.

• Here may also be mentioned the tests made by Dr. Morisse, a member of the Count of Bertier expedition (1888-89) to the Upper Orinoco, where he made practical trials with Hevea latex. Rousseau writes about this in his excellent treatise on rubber and gutta-percha : " His tests to find a method for quickly coagulating the latex (and at the same time retaining the quality of the caoutchouc) by means of several substances, led to the following results :—

" 1 part 90 per cent. alcohol coagulates 6 parts of caoutchouc. The result is a fine, excellent, and pure white rubber, which does not become yellow even in the course of time. *This method is too expensive for practical use.*

" Chloride of iron decomposes the latex in proportions of 1 to 9. The caoutchouc obtained is a coarse-grained dust, has an ugly colour, and does not easily cohere.

"1 part of alcoholic solution of corrosive sublimate decomposes 11 parts of latex, and gives an excellent caoutchouc.

"1 part chloride of calcium decomposes 15 parts of latex, but it is very difficult to preserve this hygroscopic salt in a hot climate where the air is always full of moisture.

"Muriatic acid has a coagulation power of 1 : 5; nitric acid has still less influence.

"Crude carbolic acid has the power of 1 : 18, but the most powerful of all the materials which have yet been tried is sulphuric acid. A solution in water 1 : 50 is sufficient to coagulate 10 litres of latex: the effect goes even far enough to permit a solution of 1 : 100, but it is only successful when the material is shaken and a long time given for development.

"Iodic acid seems only to be effective through the accompanying alcohol. Other chemicals which were tried gave no remarkable results. Of these may be mentioned potash, soda, ordinary salt, carbonate and bi-carbonate of sodium and potassium, bromide and iodide of potassium, ammonia, ether, chloroform, bisulphide of carbon, glycerine, arsenious acid, etc.

"Alum, which has been used for several species of rubber trees with good results, gave a negative effect with the Hevea latex. The first portions of caoutchouc coagulated by means of sulphuric acid, were spoiled by insects and fungus, which soon developed in the interior and on the surface. This gave Dr. Morisse the idea of mixing a strong antiseptic material with the sulphuric acid, and he found that phenol, which also coagulated the latex, had the right effect. The traces of the coagulation did not disappear until six months after the treatment, when the caoutchouc was so dry that no pernicious effects were to be feared. After many tests had been made, the following mixtures were found to be worthy of recommendation:—

Solution A.	Carbolic acid . .	4	grams.
	Alcohol for solution .		
	Water . . .	80	,,
Solution B.	Sulphuric acid . .	2	,,
	Water . . .	20	,,

"This quality effected the rapid coagulation of one litre of latex when it was shaken up in one solution.

"A solution of 1 : 60 of the first and 1 : 30 of the second acid will be found sufficient in most cases, but it must always be taken into consideration that the coagulation is influenced by circumstances such as temperature, the hygrometric conditions

of the air, time of day, etc. On some days the coagulation with the second solution was protracted and difficult. For this reason it is advisable to use the combination of A and B.

"To coagulate 1000 litres of latex, 2 litres of sulphuric acid and 4 litres of carbolic acid are required. The cost of this material is very small. Of the given quantity, 100 kilos dry, white, hard, strong and firm Para can be obtained. This shows the effect of the method.

"The latex of the Hevea is not affected by some reagents which coagulate other kinds of caoutchouc, and the desire to add new methods of coagulation to the old process of smoking cannot be recommended, especially as the production of caoutchouc by means of some solutions has always had an inferior quality as a result," etc.

Rousseau's opinions can only be endorsed. Para rubber owes its quality to its careful and most excellent preparation; to give this up would mean the courting of considerable and unavoidable losses. The antiseptic influence of carbolic acid is problematical, only creosote can produce total sterilisation.

III. 6.—Chemical Decomposition by Addition of Organic Acids

This method is employed in Madagascar, Gambia, Peru, Guatemala, and Nicaragua. In some cases it is brought about by the addition of an organic acid; in others by the use of an infusion, the chemical composition of which is not quite certain, but the effect can only be traced to the existence of an organic acid.

From the examination of the African sorts already mentioned, it seems to be citric acid which is used in the coagulation of the Landolphia latex. Morellet writes about this: "We found frequently in the Madagascar caoutchouc under observation, grains which we recognised as coming from the Aurantiaceæ. At first we could not discover how these grains came into the caoutchouc, as their frequency excluded the theory of accident. We came to the conclusion that the process of preparation had something to do with it, and that the juice of the Aurantiaceæ, which contains citric acid, was used for coagulating the latex. This view has been substantiated by travellers who explored the country."

Cousin maintains that he produced a nearly transparent, amber-coloured caoutchouc during his stay at Casamanza by the use of the same method, which caoutchouc had a remarkable elasticity and durability. This assertion may be doubted; when mineral acids are the cause of a too sudden coagulation,

the same applies equally to vegetable acids, which are, in addition, a breeding-place for all kinds of microbes, causing decomposition. The superiority of the method is doubtful. A substantiation of this view may also be gleaned from Madagascar reports, which refer to the adoption of coagulation by means of sulphuric acid instead of citric acid, which was formerly the only one in use. Some Peruvian collectors use organic acids for treating the Hancornia latex, and the fruit juice chosen is called "sachacamote" by the seringueiros, and is taken from a species of the lianas. The same process is employed for the Castilloa latex in Guatemala and Nicaragua. The coagulation is brought about by an infusion of the roots of a bindweed, the *ipomea bona nox*, so frequent in Central America. The decomposition of the latex is caused by an organic but not definable acid. The caoutchouc produced contains a foreign resin, which lessens its industrial value, as it can only be removed with difficulty and is harmful in working. The same latex supplies a very elastic, strong and valuable caoutchouc when treated by another method.

IV.—Coagulation by a Combination of Natural or Artificial Heat with Chemical Decomposition.

In Gambia (Casamanza) and on the Ivory Coast the Landolphias and lianas are treated by the following method:—

The collector makes a slight cut in the liana and presses the bark together. Each mark is brushed over with salt water, and the 2 to 2½ inches long cuts stand close, not leaving more than four inches space between. The latex oozes at once as a thick white fluid. Caoutchouc and other contents separate immediately under the influence of the salt water, the caoutchouc contracting and forming little lumps. The collector takes from every cut a little caoutchouc and forms it in his hand into a ball. As the material is very tough, each portion remains in contact with the cut, forming a thread from the bark to the hand of the labourer. The caoutchouc is continually issuing from the cut in the form of a thread, the latex coagulating at once, and all that the labourer has to do is to wind the thread into a ball. The stretching and pressing between the fingers glues the threads together as soon as they are covered by a fresh layer. The formation of these threads can only be seen on the surface of the ball, and to unwind the ball is impossible. The cuts have to be treated anew with salt water from time to time. The caoutchouc obtained is nearly white at first, but it becomes darker and takes a red tinge.

The weight of the rolled up balls varies from one to two pounds, but sometimes balls up to 4½ pounds are to be seen. As the labourer cannot hold these balls between his hands, he lies down on his back, rests the ball on his body and holds it in position with his hands, in which attitude he continues rolling until the latex is exhausted.

This process, by which natural and artificial heat act uninterruptedly in combination with a strong antiseptic on a small quantity of rubber, can only be recommended where local conditions or the composition of the latex make smoking impossible. Each individual thread is exposed to the air and also to the heat of the labourer's hands. The evaporation is thus pretty thorough, but the operation is very laborious.

A variation on the method must also be mentioned. It supplies a pure product without any addition of vegetable or mineral substances, such as could be added by the collector if he desired to increase the weight. These acts, however, carry their own punishment, as, if the suspicion of the buyer is once aroused, it is difficult for the collector to find a dealer willing to purchase without submitting the rubber to stringent tests.

V.—Separating the Caoutchouc by Beating.

It has already been stated that a short description of this method, recommended by Ph. Rousseau, would be given. The idea of producing caoutchouc in the same way as butter has some attractions, as it would be a very simple and cheap process. It is unfortunate that the proposal becomes impracticable on closer consideration. If the butter has been separated from the milk, a slight pressing is sufficient to remove all superfluous fluid, and a little kneading with salt for a time has an antiseptic effect. Caoutchouc cannot be treated in the same way; even when it is made from the best latex the drawbacks so frequently mentioned already are always attached to it.

This completes the description of the various methods of coagulation of the raw caoutchouc. The results of the experience gained hitherto from all the tests and researches can be condensed in the following points:—

1. The density of the caoutchouc latex must be considered when a method is chosen. The Manihots supply a thick latex, and the fluid from the Heveas, Castilloas, Landolphias, and Ficus is more liquid. It would be wrong to treat both by the same process.

2. It is always desirable to produce a caoutchouc with very little moisture, and as entire an absence as possible of matters liable to set up fermentation. The caoutchouc must not contain any foreign materials; neither accident nor design should be allowed to raise suspicion or lower the name and value of the product. Two methods cannot be too strongly recommended: the (I. 1 a) coagulation by smoking, and the (IV.) coagulation by natural or artificial heat with addition of ordinary salt.

3. The use of organic or mineral acids, alum, and the addition of water, under whichever form it may be suggested, should be avoided, as it always affects the quality prejudicially.

4. An important point is the form in which the caoutchouc is stored. If it has been prepared with the addition of other fluids, the larger the pieces the shorter time does the caoutchouc keep. The explanation is simple. The greater the surface the more moisture is evaporated; the product gains in quality by drying, and decomposition is hindered.

5. The mixing of latex from various sources is strongly to be deprecated, as it always tends towards inferior qualities. The inferior latex will always influence the better material and drag it down to its own level, without benefiting by the addition.

6. Knowledge of the chemical composition of each kind of latex would undoubtedly help to discover in every case the best method of preparation. Unfortunately there is not sufficient data. A search in this direction would be of the greatest benefit to the industry, and chemists might well give these points their consideration. Adrian has tried to give an exact analysis of the latex of the Indian Ficus. The composition of the Hevea latex will be made the subject of a closer study in another chapter; of the composition of other kinds of latex very little is known. But it is necessary that we should know, as it would enable us to find the best methods of coagulation and storage of the different qualities of caoutchouc.

7. A clearer knowledge of the milk veins, their basis and development with regard to the other organs of the bark, would be equally advantageous. Little has hitherto been done in this direction, but these researches would add greatly to our knowledge of the qualities and the treatment of caoutchouc. Morellet has dissected the barks of several caoutchouc plants; his example should be followed, and the researches might be extended to all caoutchouc plants and the land of their growth.

IV.—Commercial Notes.

THE raw rubbers known on the international market can be divided, according to their origin, into the following main classes :—

1. American caoutchouc,	South American caoutchouc. Central ,, ,,
2. African ,,	East African ,, West ,, ,,
3. Asiatic ,,	
4. Australian ,,	

The designation of the different kinds in the trade is not always regular; individual kinds are often called by the name of the province, from which they come (although other places sometimes send the same kind), or the export station which serves as a trading centre labels all quantities going through it with its mark. At other times the title is taken from the shape in which the caoutchouc comes on the market.

The most important forms on the market, everywhere called by English names, are :—

1. *Balls.*
2. *Bottles* : lumps which are made on the wooden forms with handles, and taken from the form by a side cut; the pieces have a bottle-necked appearance, whence the name.
3. *Buttons* : smaller balls.
4. *Biscuits* : thick-cut pieces of oblong shape.
5. *Cakes* : the same, but rounder and of a more irregular shape.
6. *Clusters* : small marbles in rows, or little balls sticking together having a general resemblance in form to a bunch of grapes.
7. *Flakes.*
8. *Flates* : thin sheets and strips.
9. *Heads* : larger balls, mostly remnants of Para rubber scrapped together (*Negroheads*).
10. *Lumps* : pieces of irregular shape not pressed.
11. *Marbles* : small balls.

12. *Negroheads*: see Heads.
13. *Niggers*: kneaded balls of different sizes, often deformed and the original shape not recognisable.
14. *Oysters*: two thin round or irregular-shaped sheets which hang together at one end like the shells of an oyster.
15. *Paste*: very soft masses, nearly fluid.
16. *Sausage*: finger- or sausage-shaped pieces like spindles, but without the wooden sticks.
17. *Scraps*: scraps of rubber often lumped together in large balls.
18. *Sheets*: known by the name.
19. *Slabs*: thin sheets.
20. *Spindles*: threads rolled round a wooden stick, often cut open to remove the wood.
21. *Strips*: the name suggests the meaning.
22. *Thimbles*: pieces cut in small squares.
23. *Tongues*: sheets, tongue-shaped and thin.
24. *Twists*: composed of threads, like a ball of wool.

General View of

I. American Rubber

TRADE NAME.	GEOGRAPHICAL ORIGIN.	BOTANICAL ORIGIN.	METHOD OF COAGULATION.	PLACE OF EXPORT.	MARKET.	PACKING.	FORM.
Fine Para; Siringa Fina; Island fine, soft cure	Brazil, Lower Amazon	Hevea	I. 1 a	Para (Belem), Manaos, Iquitos	Liverpool, London, Hamburg, Havre, New York	Chests of 130-140 kg.	Formerly came in figures, flasks, pears, shoes, but now in biscuits or loaves; the pieces weigh usually 15-20 kg., but sometimes as much as 50 kg.
Entrefine; Island entrefine or medium; Para ½ fine; Entrefina grossa	Do.	Do.	I. 1 a, and I. 2 c	Do.	Do.	Do.	Do.

[1]A dirty milky white is always a sign of dampness—*i.e.* the serum or uncoagulated latex is enclosed in the
although it

All the designations are changeable; qualities known thirty years ago have disappeared to make room for others from the same country and the identical plant, the products of which have simply taken another name when they changed their method of production. It has also been noticed that higher prices have been paid for inferior qualities when ticketed with a new name, but the branding is not sufficient, and in most cases the caoutchouc has to show an improvement when changing its title.

Under these circumstances, it might seem superfluous to describe each individual kind. With the daily improvement in production and the appearance and disappearance of caoutchouc qualities, much that might be said to-day would be stale or out of date by to-morrow. A short review of the best-known kinds may therefore be given as sufficient.

Crude Indiarubbers

I. South America

Appearance.	Section.	Smell.	Adulterations.	Valuation.	Remarks.
Dark brown or black	Dark near the outside, whitish inside; the separate layers are called leaves or skins.	Like smoked bacon	Few foreign bodies often mixed with the latex of *Mimusops elata*, Marcandaruba; moisture varies according to time of harvesting	Strong, and very elastic	The biscuits often bear the name of the factory. The harvest is in the wet season, end of June to mid October. In wet weather gathering is impossible, and the latex contaminated, little indiarubber. Borracha comes on the Brazil market from the end of July to the end of December.
Do.	Very different from that of fine Para on account of difficult coagulation; unsmoked parts are a dirty white, the smoked surface a bistre brown[1]	Less pronounced than with fine Para. Like methylamine	Few foreign bodies, but chiefly bark; moister than above	Weaker	The large loaves and biscuits of fine Para are cut through partly at the purchasing place and partly at Para, and all pieces not thoroughly smoked and showing unsmoked streaks are sorted out as entrefine.

indiarubber. A horny, translucent appearance, on the other hand, is a sign of purity and good quality seldom occurs.

Trade Name.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Place of Export.	Market.	Packing.	Form.
Negroheads; Island Negroheads; Sernamby; Sernamby de Borracha (De Iebe); Cabeca de Negro	Brazil, Lower Amazon	Hevea	I. 1 a, and I. 2 c	Para, Belem, Manaos, Iquitos	Liverpool, London, Hamburg, Havre, New York	Chests or tuns of 200 kg.	Comes on the market either in great blocks, or more usually in irregular pieces the size of the hand, which stick clonger with the tight packing
Caviana	Caviana, an island at the mouth of the Amazon	Do.	I. 1 a	Para	Do.	Do.	...
Cameta	Para	Do.	Do.	Cameta Para	Do.	Do.	Like Negroheads
Upriver Para fine, hard cure; Sertao fina	Upper Amazon	Do. Micranda	Do.	Iquitos, Manaos, Para	Do.	Do.	Biscuits, loaves, smaller, harder, and drier than those of Island fine
Upriver Entrefine or medium; Sertao entrefine.	Do.	Do.	Do. and I. 1 c	Do.	Do.	Do.	Do.
Upriver Negroheads; Sernamby; Sertao; Cabeca de Negro	Do.	Do.	Do.	Do.	Do.	Do.	Like Island Negroheads
Virgin sheets or Matto Grosso Para (Para blanc)	Matto Grosso (Brazil)	Hevea	III. 5	Manaos, Monte Video, Rio Janeiro	New York, London, Hamburg, Liverpool	...	Large regular loaves 60 cm. long and 30 cm. wide and 15 cm. thick; smaller loaves of half size
Ceara scraps; Maniçoba	Ceara (Brazil)	Manihot Glaziowii (Maniçoba or Leitera)	I. 2 c	Ceara	Liverpool, New York, Hamburg	Bales	Little strips or tears massed into lumps, the lumps being pressed together while fresh in the packing, cohere into blocks up to 150 kg.
Pernambuco; Mangabeira	Pernambuco	Hancornia	III. 5	Pernambuco	...	Chest and bales	Right-angled plates of various sizes, often 150 × 60-70 × 8-10 cm.
Maranham	Maranham (Brazil)	Do.	...	Maranham, Santos, Bahia	...	Chests	

APPEARANCE.	SECTION.	SMELL.	ADULTERATIONS.	VALUATION.	REMARKS.
Black.	Yellowish white with black veins	Less pronounced than with fine Para. Like methylamine. Often mouldy	With sand and inelastic "dead" rubber; much moisture	Deficient in durability	... ...
...	Very smooth	...	...	...	Excellent sort.
Paler than Negroheads	Yellowish white or quite white	...	...	...	... ...
Dark brown to black	Dark outside, light inside, flaky	Smoky	..	Very pure	... ...
Do.	Like Island entrefine	Smell less smoky	...	...	... ...
Black	Paler, with dark veins	Not smoky	...	...	... ...
Pale brown	Straw yellow or greenish marbling, especially at the edges	...	...	Weaker than brown Para	Harvested from August to February. As with Para we distinguish fine, ½ fine, and Sernamby.
Pale and dark amber	Pale amber, on stretching white and opaque	Very marked and unpleasant, increased by damp heat	Always with vegetable débris, often with sand. Dampness up to 15%	Fairly strong and esteemed when of good quality	Ceara indiarubber is freed from serum by pressure.
Reddish yellow with an efflorescence	Orange yellow many holes filled with alum containing serum	...	...	Inelastic little esteemed, sometimes used for the sake of its fine colour	Is made hard and brittle in time by the alum. This sort will soon be discarded for Maranham.
Smooth and shining without efflorescence	Pinky white, turning a wine red in the air	...	...	Stronger and more elastic	The serum contains sugar.

Trade Name.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Place of Export.	Market.	Packing.	Form.
Bahia	Bahia	Hancornia	I. 2 a	Bahia	...	...	Irregular masses up to 20 kg.
Cartagena (Esquebo)	Colombia	Hevea	I. 2 c	Cartagena, Sevanilla	Havre, New York, London, Hamburg	Chests, barrels, and sacks	Big lumps up to 80 kg. formed of plates or strips folded together like Nicaragua scraps
Cuidad Bolivar, Colombia, Virgin	Venezuela	Hevea, Callotropis procera, Hancornia speciosa, Sapium biglodulosum (Lechero)	I. 1 a, often III. 5 (Morisse)	Bolivar, Manaos	Hamburg	Boxes or tins	Like Para
Cayenne	French Guiana	Hevea	I. 1 a,	Cayenne	France	Do.	Do.
Caucho slabs (Peruvian slabs)	Peru	Hevea, Cameraria latifolia, Hancornia speciosa	I. 2 a, III., 6 and 5, cut to get rid of the serum	Iquitos, Manaos, Para	New York, Havre, Liverpool	Boxes	Big blocks, or like fine Para
Peruvian balls Sernamby de Perou, Sernamby de Caucho	Do.	Do.	Do.	Do.	Do.	Do.	Like Negroheads
Guayaquil in plates	Ecuador, Colombia	Castilloa	III. 5 and 6	Guayaquil	Hamburg, New York, London	Sacks	Large plates, up to 100 × 70 × 5 cm.
Mollendo	Bolivia	...	...	Mollendo, on the coast of Peru	...	...	Biscuits and sheets

I. American Rubber.

Trade Name.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Place of Export.	Market.	Packing.	Form.
Colon and Panama	Central America	Castilloa	III. 5 and 6	Colon	...	...	Strips 10 cm. thick and up to 3 metres long
Mexican and other West Indian and Central American sorts	Vera Cruz, Taumapilas, Tabasco, Guerero, Baraca, Repic Chiopas	Do.	I. 1 b, and an unknown process	San Benito Tonala, Vera Cruz, San Salvador	New York, Hamburg, London	Boxes, sacks	Plates 1-4 cm. thick and 60 cm. long by 50 wide. Sometimes in balls of 5-6 cm. diameter.
Guatemala	Guatemala	Do.	III. 6, with Ipomea Boya-nox	Guatemala Champerico	New York, but of late Hamburg chiefly	Sacks	Plates.

Appearance.	Section.	Smell.	Adulteration.	Valuation.	Remarks.
Reddish orange	Pinky white. Holes filled with serum and uncoagulated latex	...	Wood, sand, loam, very damp	Not much esteemed	... ...
Black	Brown, black, green	Like methylamine and mould	Earth	Fairly esteemed	There is another sort of Cartagena rubber which has been longer known and has the characters of Guayaquil.
Like Para	Like Para	Slightly smoky	Often mixed with the juice of Massaranda and Pindar	Like Para and it is often sold as Para	Harvest, November-April. Sometimes got on the Orinoco by felling the trees. Loses quality by being mixed with other juices.
Do.	Do.	Do.	Fairly pure	Like Para	According to Coudreau the exploitation is much neglected.
Deep black with a grimy surface	Yellow, turning slate grey in time; very porous	...	Much sand and water	Very elastic and prized, but the colour is disliked	The harvest begins in August. If the rubber is boiled in water it turns to a dirty white. The decoction is a strong purgative.
...	...	...	...	Sernambillo is better than Negroheads, as it is less porous and contains less water	
Blackish	Blackish green, very damp, and with blisters of water	...	Very impure; earth and veg. débris; much water	Sometimes very elastic, sometimes dull and full of earth, like Cartagena	... ...
...	...	...	...	...	... ...

2. Central America.

Appearance.	Section.	Smell.	Adulteration.	Valuation.	Remarks.
...	...	...	...	As Cartagena	... ...
Black	Black, brown, yellowish-green, sometimes a brown liquid flows from the cut	...	Sand, earth, leaves; sometimes splinters of wood	Very strong	... ...
Black	Black, partly yellowish-green and brown, contains a thick liquid (uncoagulated rubber)	Very characteristic	Dirt, bark, earth	Sometimes as strong as Guayaquil; sometimes less so	... ...

TRADE NAME.	GEOGRAPHICAL ORIGIN.	BOTANICAL ORIGIN.	METHOD OF COAGULATION.	PLACE OF EXPORT.	MARKET.	PACKING.	FORM.
Nicaragua, Mexican, Ecuador, and West Indian scraps.	Nicaragua, Mexico, San Salvador, Ecuador	Castilloa	II. 3	Greytown, Vera Cruz, Guayaquil, San Salvador, Quito	Hamburg, New York, London	Boxes or tins	Sausages as thick as the arm, or balls at least as large as the head. Sometimes dice of 60-80 cm. side. They are always masses of strips, tears, and scraps of sheets.

II. African

TRADE NAME.	GEOGRAPHICAL ORIGIN.	BOTANICAL ORIGIN.	METHOD OF COAGULATION.	PLACE OF EXPORT.	MARKET.	PACKING.	FORM.
Senegal and Bissao balls	Senegambia Soudan, Bissago Islands	Landolphia, Calotropis procera, Ficus khal	IV.	Rio Nunez, Bissao, Bolama	Hamburg, Marseilles, Liverpool	Casks	Balls or plates
Gambia balls	Senegambia, Bathurst, Bissagols., Soudan	...	...	Daku, Bathurst, Bolama, Bissao, Casamanca	Hamburg, Marseilles, Liverpool	Casks and sacks	Balls.
Casamance (Boalam)	Table-land on the right bank of the Casamance	Landolphia	I. 2 b	Boulam	Marseilles	Chests and tins	Like Senegal rubber
Casamance (Gambien)	Left bank of Casamance	Do.	IV., sometimes III. 6. Citric acid	Zighinchor	...	...	Pieces of 300-800 grammes, or even 2 kg.
Sierra Leone, Niggers, Massai Niggers	Sierra Leone, French Guiana	Landolphia, Diander, L. owariensis L. florida	I. 2 b	Freetown	Liverpool, Hamburg, Marseilles	Barrels and casks	Balls
Sierra Leone twist	Sierra Leone	Do.	...	Conakry, Rio Pungo, Mano	...	...	...

Appearance.	Section.	Smell.	Adulterations.	Valuation.	Remarks.
Blackish	Usually blackish and shiny; sometimes yellow but soon blackened in the air	...	Little moisture, some cork, and sometimes falsified with sand	Much prized; ranks next to fine Para	... ...

Rubber.

Appearance.	Section.	Smell.	Adulterations.	Valuation.	Remarks.
Brownish black	White and pink	...	Much moisture, sand, bark, and dirt	Sometimes very strong; fairly esteemed	... ...
Brownish white and black	Pinky white	...	Moisture, sand, a little bark	Pure dry balls; much prized; lower qualities less so	... ...
Dark brown	Grey, passing to cream and reddish; holes and much sand	Bad	Mud, earth, and sand	Small	Mostly comes on the market in March.
At first white, then reddish brown	Concentric layers, reddish-brown to white; white predominates, but exposed to air assumes the red-brown shade of the outside. Sometimes concentric veins black, white, and pink. Rubber got by the III. 6 method has a pale amber colour	...	Few foreign bodies. Rather damp	Rather strong	This would be an excellent rubber if it was not mixed with other kinds of latex. The black rubber in these is very sticky, and works injuriously on the paler stuff. A good, very strong and elastic rubber is got by the III. 6 method.
Red, red-brown, white	Red, red-brown, white	None	Sometimes very pure; sometimes mixed with bark and earth; sometimes dry; sometimes damp	Dry red balls are much prized; but not soft wet ones	... ...
Brown	White	...	Sometimes very pure, but often mixed with earth and bark inside, and with only the outside good	Strong and much valued	... ...

Trade Name.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Place of Export.	Market.	Packing.	Form.
Liberia	Liberia	Landolphia	IV.	Monrovia	Hamburg, London	Casks	Balls and lumps
Grand Bassam (Assinien) (Axim) (Attabar)	Ivory Coast	Ficus, Landolphia, Urostigma	IV.	Grand Bassam	Liverpool, Hamburg	Casks and chests	Lumps
Cape Coast lumps	Gold Coast	Kickxia	...	Monrovia, Grand Bassam	London, Hamburg	...	Big lumps
Accrah lumps	Do.	Do.	...	Saltpond, Winnebah	Do.	Casks	Do.
Saltpond lumps	Do.	Do.	...	Saltpond	Do.	...	Do.
Lagos lumps	Lagos	Do.	...	Lagos	Do.	...	Do.
Cameroon balls	Cameroon	Do. Landolphia	...	Cameroon, Malimba, Batanga, Campo	Do.	...	Small balls
Batango balls	Do.	Do.	...	Do.	Do.	...	Do.
Bata thimbles	Do.	Do.	...	Do.	Do.	...	Do.
Niger Nigers	Niger Territory	Landolphia (partly root rubber)	III. 5	Akassa, Barrata	Liverpool	Sacks and casks	Balls pressed together
Gaboon balls	French Congo	Landolphia florida. L. petersiana, L. owariensis	Unknown	C. Lopez, Gaboon, Bata Eloby, Mayumba	Hamburg, Liverpool	Casks	Large and small balls
Gaboon tongues	Do.	Do.	Do.	Do.	...	...	Small longish balls
Red Kassai	Congo State	Landolphia	I. 2 c.	Leopoldville, Boma, Cabinda	Antwerp	...	Small balls stuck together in tens, so as to form a pair of short tufts
Black Kassai	Do.	Do.	Unknown, probably I. 2 c.	Do.	Do.	...	Tufts
Kassai strips	Do.	Do.	Do.	Do.	Do.	...	In rolls
Black ball Kassai	Do.	Do.	Do.	Do.	Do.	...	Unequally sized masses, pressed together into balls

Appearance.	Section.	Smell.	Adulterations.	Valuation.	Remarks.
White, brown, black	The balls white and pink, the lumps green, yellow, and white	The balls have little smell; the lumps a very bad one	The balls are pure, but rather damp; the lumps very wet	Fairly good	... ...
Black	Dark and light green	Bad	Fairly pure, but damp	...	... ...
Dark	Yellow	Do.	...	...	... ...
Do.	Yellow, brown	Do.	Often with earth	...	... ...
Do.	Do.	Do.	...	...	... ...
Do.	Silky-white	Do.	...	...	Silk rubber
Black	Flesh-coloured to red	Do.	...	...	... ...
Do.	Do.	Do.	...	...	... ...
Do	Do.	Do.	...	...	.. ...
White, red	White; the root rubber, partly red	Little	Sometimes pure, but damp; much bark in the root rubber	The white balls are strong and prized; the root rubber is soft and resinous	... ...
Black and grey	The large balls pink, blue, and red; the small grey, white, and green	Bad	Bark and sand; very damp	The large balls are strong and prized, but the small are soft and of less esteem	Action of bleaching powder
...	White and grey	...	Sandy, outside damp; sometimes limey	Little valued	Do.
Red	...	...	Very few	Considered the best Congo sort	... ...
Black	...	...	Often mineral and volatile bodies	Less valuable	... ...
...	...	...	Volatile fermenting bodies.	Fairly strong	... ...
Black	...	...	Neither sand nor wood, but a good deal of fermenting matter	...	... ...

Trade Name.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Place of Export.	Market.	Packing.	Form.
Ordinary Upper Congo	Congo State	Landolphia	Unknown probably I. 2 c	...	Antwerp	...	In masses of balls pressed together
White Upper Congo	Do.	Do.	III. 6 by means of the plant Bossanga	...	Do.	...	Balls
Equator	Do.	Do.	Do.	...	Do.	...	Balls stuck together
Lopari	Do.	Do.	Do.	...	Do.	...	Balls
Busira	Do.	Do.	Do.	...	Do.	...	Do.
Aruwimi, Mongola, Bumba	Do.	Do.	Sometimes with water	...	Do.	...	Balls up to 5 kg.
Uelle	Do.	Do.	...	...	Do.	...	Plates up to 10 kg.
Lower Congo thimbles and balls	Do. Angola	Carpodinus, Clitandra	By boiling and beating	Ambriz, Kissembo, Macalla, Maldai	Hamburg, Rotterdam, Lisbon, Antwerp, Liverpool	Sacks and casks	Cut into square pieces
Kidinga balls	Do.	Do.	Do.	...	Do.	Do.	Do.
Wamba thimbles	Do.	Do.	Do.	...	Do.	Do.	Do.
Luvituku thimbles	Do.	Do.	Do.	...	Do.	Do.	Do.
Landa balls	Do.	Do.	Do.	Landana	Do.	Do.	...
Angola thimbles	Angola	Do.	Do.	Ambriz, Loanda, Benguela, Mossamedes	Lisbon, Antwerp	Do.	...
Loanda thimbles	Do.	Landolphia	I. 2 b, II. 4, I. 2 a, IV.	S. Paul de Loanda	Marseilles, Bordeaux, Nantes, Havre	Chests and tuns	Thimbles or dice from 5 mm. to 3 cm. size
Loanda Niggers	Do. (Loanda)	Do.	I. 2 b, I. 2 c, IV.	...	Hamburg, Lisbon, Liverpool, Rotterdam	Sacks and casks	Balls sticking together in chains

Appearance.	Section.	Smell.	Adulterations.	Valuation.	Remarks.
...	...	...	Bark and about 8% water	Strong	The first sort imported from the Congo
...	White	...	Very pure, 6-8% water	Very strong	... ...
...	...	...	Very pure 5-7% water	Strong and good	... ...
...	...	...	Volatile and fermenting bodies	Very elastic, and as much esteemed as Equator	... ...
...	...	...	...	Much prized	Nearly as much as Equator.
...	...	Very bad and penetrating	As much as 35% of fermentable matter	Good	... ...
White	...	...	Fairly pure; volatile, but only occasionally fermentable bodies	...	... ...
I. Red and black; II. Black and reddish	I. Red and black; II. Red	...	I. Pure, occasionally sandy; II. Contains bark, and sometimes earth.	I. Strong, but sometimes resinous; II. If dry much sought for, but not if wet	... ...
Do.	Do.	...	...	...	... ...
Do.	Do.	...	...	...	... ...
Do.	Ds.	...	...	...	... ...
Do.	Do.	...	...	...	... ...
Do.	Do.	...	...	...	... ...
Slate-grey	Shiny slate-grey with white dots	Bad, like dry Congo	No foreign bodies	Inclined to become soft and greasy; the most prized Angola sort	To be kept cold.
I. Red and black; II. Reddish	I. Red and black; II. Red	Very little	I. Pure and dry II. Much bark, sometimes sand	I. Strong and much prized; II. Weaker, but if dry and not oxidised, fairly prized; resinous	Is gradually disappearing from the market, being replaced by the following sort.

Trade Name.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Place of Export.	Market.	Packing.	Form.
Angola Niggers, Angola Negrohead	Angola	Landolphia	I. 2 b	...	...	...	Irregular balls, 3·5 cm. in diam.
Benguela Niggers	Benguela, Mossamedes	Do.	...	Benguela	Hamburg, Lisbon, Liverpool, Rotterdam	Sacks	In sausages and in balls joined together in chains
Mozambique marbles	Mazambique	L. Kirkii, L. petersiana, L. florida	III.	Mozambique, Inhambane, Beira, Ibo, Quilimane	Hamburg, London	...	Small balls squeezed together
Mozambique balls	Mozambique, German E. Africa	...	IV.	Mozambique, Bagamojo, Kilwa, Dar es Salaam, Lindi	Hamburg, London, Rotterdam	Sacks and boxes	Small and large balls
Mozambique spindles	Mozambique	Landolphia	I. 2 c, wrapped on wood	Beira, Inhambane, Ibo, Quilimane	Do.	Sacks	Spindles
Madagascar black	Madagascar	Willughbeia	IV.	Nossi Be, Majunga	Hamburg, Marseilles, London	Sacks and boxes	Big round pieces, often cut in two
Madagascar pinky	...	...	...	Tamatave	...	...	...
Madagascar Niggers	...	...	...	Nossi Be, Fort Dauphin	...	Mats, casks and sacks	Big balls

Appearance.	Section.	Smell.	Adulterations.	Valuation.	Remarks.
Reddish brown	Reddish brown and nearly transparent, with the middle very soft, but hardening in a few days in the air	...	Rather damp. Some small vegetable débris	Less strong; rather sticky	... ...
Reddish	Red	...	Dry; much bark	When dry much prized; but not fresh goods. Pale inside and oxidising easily	... ...
Black and reddish	Red, rarely white	...	Much bark, sometimes sand. Damp	...	... ...
Brown and pink	Red, bronze pink, white	None	The best is very pure and dry. Inferior sorts contain sand and vegetable débris, and are damp	The best, separately cut balls are valued for their small waste and high quality. Even inferior sorts are sought for	... ...
Brown and red	Red and brownish, rarely black	Do.	Bark and sand. Dry	Much prized if unadulterated, as they make little waste and are very strong	... ...
Black	White, pink, yellow, green	Bad	Earth and vegetable débris. Very damp	Less prized than pinky	Suitable for hard rubber making.
Brown and black	Pink, white	...	Pure, but damp	Much prized. Very elastic, though not very strong	A special favourite in America.
Black and yellow	Brownish, white, black, yellow	Slight	Dry, but usually much adulterated with earth	Yellow W. Coast Niggers are usually soft but often, like the E. Coast Niggers, very strong and much prized	... ..

Trade Name.	Geographical Origin.	Botanical Origin.	Method of Coagulation.	Place of Export.	Market.	Packing.	Form.
							III. Asiatic
Assam	N.-W. Bengal, Brahmaputra	Ficus, Urceola	I. 1 b, II. 3, I. 2 c	Calcutta	London	Sewn in jute and wrapped with palm leaves	Lumps up to 150 kg., which cling fast to the wrapping as this rubber soon gets tough and smeary
Rangoon	Burmah, Cochin-China, Annam, Tonkin	Ficus elastica, Urceola esculenta	...	Rangoon	...	...	Irregular masses
Penang	Sumatra and Sunda Islands	Ficus cynanchum	...	Penang, Singapore	London, Hamburg	Boxes	Big halved lumps and balls
Ceylon	Ceylon	Manihot Glaziowii	...	Ceylon	London	Do.	Irregular dice of about 10 cm.
Java and Padang	Java, Sumatra, and other Sunda Islands	Ficus	I. 2 c	Batavia, Padang	Hamburg, Rotterdam	Boxes and baskets	Big halved lumps and balls
Borneo	Borneo	Urceola, Willughbeia, Dijera, Callotropis	III. 5	Singapore	Hamburg, London, Havre	...	Big lumps, flat pieces and balls
Djambes	Sumatra	Urceola	...	Singapore	London	Sewn in jute	Balls and plates
Borneo (Ben Koelen)	...	...	...	Elockpura	...	...	Thin plates
							IV. Australian
New Caledonia	New Caledonia	Ficus prolixa, Urostigma prolixa, Artocarpus integrifolia	I. 1 a	Port Vila	Marseilles	...	Biscuits, like Para, of 6-10 kg. Also balls
Noumea	Do.	...	...	Noumea	Do.	...	Do.
New Guinea balls	New Guinea	Ficus	...	Port Moresby	...	...	Strings of little balls
Samarei	Do.	Do.	...	Samarei	...	...	Do.

Appearance.	Section.	Smell.	Adulterations.	Valuation.	Remarks.
Indiarubbers.					
Brown	Dark, and grey or reddish, with white, almost transparent, places	...	Damp sand, earth, wood	Formerly much prized, but now less so, as the quality is not so good	Is disappearing from the market.
Very dark brown	Shiny, marbled, red, white, and black	...	Always with wood	Less valued than the last	... ...
Red, brown	Red, pink, whitish	...	Wood and a little earth. Sometimes damp	Good dry stuff much prized, but not soft sticky stuff	... ...
Black	Brown and translucent	...	Sand and earth	Fairly strong	Well cultivated. Only recently introduced.
Red, brown	Glossy, red, pink, white	Little	Wood, a little earth. Sometimes damp	If good and dry prized, but not if damp and sticky	... ...
Black	White, pink, blue, green	...	Earth and vegetable débris. Very damp	I. very strong and fine; II. sometimes soft; III. often contains "dead" rubber	... ...
Brown, red	Greenish red	...	Clay and much water	Too impure to be much prized	... ...
Brown	White inside	...	Fairly pure	Good quality	... ...
Rubbers.					
Light brown to black	With white veins	Smoky	Very pure	Very good if not mixed with other sorts. Rather resinous	Only recently on the European market.
Do.	...	...	...	Do.	Do
Black	White or red	...	...	...	...
Do.	Do.	...	...	...	... ...

The total production of caoutchouc of all kinds in the whole world has been calculated for the last three years as follows :—

1899-1900	1900-1901	1901-1902
53,348 tons,	52,864 tons,	52,835 tons.

The total consumption of the world in the same periods amounted to

43,852 tons, 51,136 tons, 50,201 tons,

leaving a surplus, after deducting consumption from production, of

9,496 tons, 1,728 tons, 2,604 tons.

Of the total production of these years the Amazon districts (Brazil, Peru, Bolivia) supplied about 25,000 to 30,000 tons; the other American provinces (Mexico, Central America, Venezuela, Colombia, and Ecuador) supplied about 6,000 tons; East, West, and Central Africa supplied about 20,000 to 25,000 tons; Madagascar 1,000 tons, and Asia about 1,500 tons.

The European central market for raw caoutchouc is Liverpool. A few figures will show the importance of the trade.

	1887	1888	1889	1890	1891	
Import	7,330	7,900	8,750	9,900	10,680	tons.
Sale	5,890	6,485	7,760	8,610	9,480	,,
Stock	1,440	1,415	990	1,290	1,200	,,
	1892	1893	1894	1895	1896	
Import	10,400	11,330	11,560	13,720	17,300	tons.
Sale	8,950	9,830	10,285	12,640	15,640	,,
Stock	1,450	1,500	1,275	1,080	1,660	,,
	1897	1898	1899	1900	1901	
Import	15,363	18,440	16,100	17,490	17,785	tons.
Sale	14,285	16,960	14,900	15,580	15,601	,,
Stock	1,080	1,480	1,200	1,910	2,184	,,

The importance of the London market compared with Liverpool is shown by the following figures. London's share in dealing in all kinds of caoutchouc was

	1887	1888	1889	1890	1891	
Import	2,400	2,280	1,660	1,893	1,900	tons.
Sale	1,385	1,313	1,050	1,247	1,310	,,
Stock	1,015	977	610	646	590	,,
	1892	1893	1894	1895	1896	
Import	1,740	1,720	1,935	1,720	1,579	tons.
Sale	1,255	1,280	1,485	1,260	1,235	,,
Stock	485	440	450	460	344	,,
	1897	1898	1899	1900	1901	
Import	1,457	2,650	2,806	2,219	1,041	tons.
Sale	1,137	2,025	2,161	1,198	403	,,
Stock	320	625	645	1,021	638	,,

Besides Liverpool and London, Lisbon, Hamburg, Rotterdam, Amsterdam, Antwerp, Havre, Bordeaux, and Marseilles also import raw caoutchouc.

The import through Dutch ports is not large. Amsterdam has always been an unimportant place for the caoutchouc trade, and the import of Rotterdam has lost much of its importance; whereas, in 1890, a total of 591 tons came through this port, the imports up to 1898 steadily decreased to 242 tons.

The opening of the Central Congo districts has given a great impetus to the imports of Antwerp; the trade has enormously increased, as is best shown in the following figures:—

1889	1890	1891	1892	1893	1894	1895	
5	30	21	63	127	275	531	tons.

1896	1897	1898	1899	1900	1901	
1,116	1,679	2,014	3,402	5,698	5,849	tons.

Hamburg has grown immensely in importance as a raw caoutchouc market. Exact statistics as to the Hamburg market cannot be given, because the material which comes through English or French ports on the Hamburg market is not classified in the statistics as direct import, also because many importers send raw material to Genoa, Lisbon, Havre, Liverpool, London, etc., which does not touch the Hamburg

port and cannot figure in the imports, although the deal has been concluded at that place.

The direct import to Hamburg has more than doubled in nine years, as given in these statistics :—

1893	1894	1895	1896	1897	
5,053	4,771	5,424	7,191	7,577	tons.

1898	1899	1900	1901	
9,026	11,492	11,924	10,462	tons.

It is self-evident that the price is influenced by the quality and by supply and demand. The Para qualities (Fine Para and Negroheads) give the standard for the prices of the other kinds, which always range in proportion to the quotation for these two best products. As the prices of the Para qualities are again more or less dependent on the production, the respective import and export figures of Para for this rubber may be useful :—

	1887	1888	1889	1890	1891	
From Para	15,600	15,900	15,500	16,900	18,400	tons.
To England	4,400	5,080	5,920	5,600	6,000	,,
	1892	1893	1894	1895	1896	
From Para	18,920	19,730	19,500	20,710	21,600	tons.
To England	5,960	6,700	6,810	7,285	9,350	,,
	1897	1898	1899	1900	1901	
From Para	27,700	22,000	25,300	26,876	30,300	tons.
To England	7,865	9,500	7,430	10,445	12,100	,,

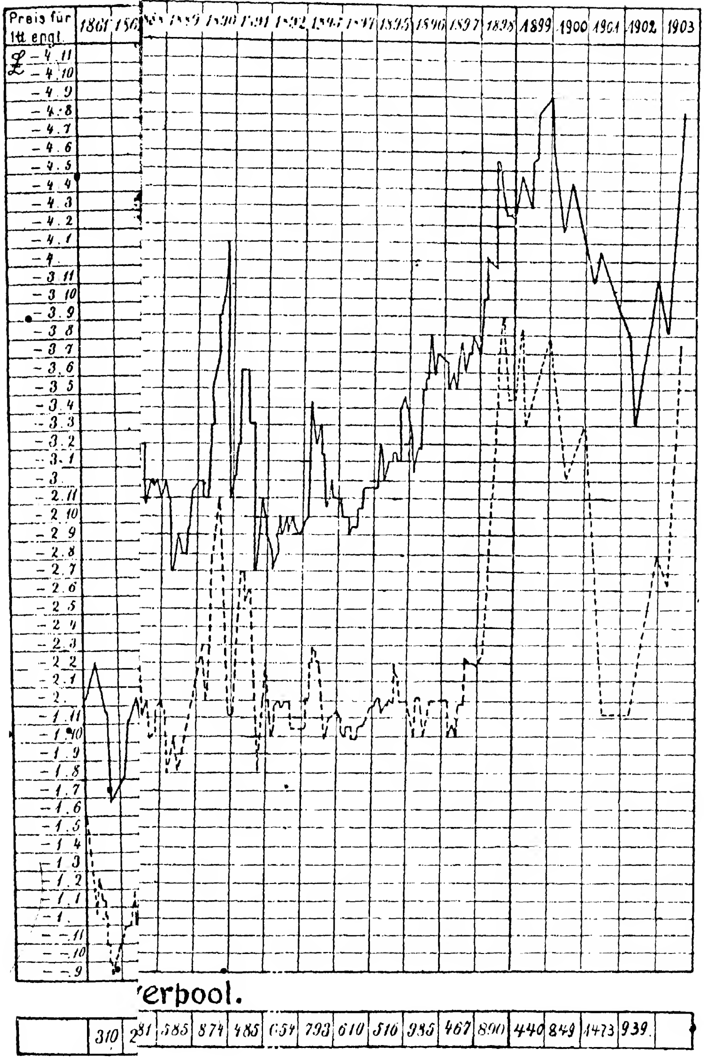
The attached graphic delineations of the price movements for Fine Para and Negroheads during the years 1861 to 1902 give a clear picture of the movements caused by supply and demand.

The lowest price for Fine Para was in September and October, 1861, when it fell to 1s. 6d., and the highest point was reached with 4s. 9d. and 4s. 11d. in 1882.

Irrespective of the boom in 1866, 1869-70, 1880, 1882-83, and 1890, and the naturally following slump, prices have been continually advanced. Since the upward movement in 1894, they have remained firm until 1900. Then a decline in prices set in, leading to sales at 3s. per lb. during July, 1902, in London, though the price rose again shortly afterwards.

ber since 1861.

=Negroheads.



V.—Chemical and Physical Properties of Raw Caoutchouc.

THE raw caoutchouc, as it appears on the international market, is, as has been stated in the previous chapters, the thickened or dried-up sap (latex) of certain species of plants. A few other points arise for consideration on closer examination of its chemical and physical properties, and for this purpose it is necessary to take into consideration, before anything else, the sap as it runs out of the plant. The latex of the Hevea brasiliensis is more or less typical of all kinds and is chosen for illustration. It is a fluid which appears white to the naked eye, in reality it has a slight tinge of amber. It contains great quantities of little ball-like particles, the diameter of which is 3½ micro-millimètres (1 micro-millimètre is 1,000th part of a millimètre). The little globules are the real caoutchouc. Although colourless in themselves, they give the whole, through their being distributed through the fluid, a milk-white look, which the liquid otherwise would not have.

The fresh latex of the Hevea is inodorous. When exposed to the air and under the influence of acids it acquires a slight methylamine-like smell which can be noticed in all raw caoutchoucs which have not been sterilised by smoking. The second Para qualities, which consist of smoked and unsmoked caoutchouc, retain this particular odour. The flavour of the fresh Hevea latex is not marked, being more agreeable and sweet than unpleasant and bitter. To find the specific weight of the latex is difficult, as it is influenced by accidental causes; on the average the latex of the lowest specific gravity contains the most elastic material. The specific weight of the latex of the Hevea brasiliensis is about 1.019 at a temperature of 57° F., and when containing about 32 per cent. caoutchouc.

The chemical composition of this latex, as it comes fresh from the tree, is—

Elastic elements	32 per cent.
Organic and nitrogenous matter .	2.30 per cent.
Mineral salts	9.70 per cent.
Resinous elements . . .	Traces.
Slightly alkaline water . .	55 to 56 per cent.

It may be said of coagulated latex, that is the raw caoutchouc as it comes on the market and is sent to the factory, that its chemical and physical properties show more or less pronounced differences, according to origin, production, and treatment. The following details may be taken as examples of the better qualities.

Raw caoutchouc has a more or less pronounced odour. Smoked kinds can easily be recognised, as they do not smell badly and have much the same taste as smoked bacon. Unsmoked and inferior qualities containing much moisture have frequently a very pronounced offensive smell. All kinds of caoutchouc are, in themselves, tasteless.

The specific weight is 0.92 to 0.96.

Up to the freezing-point, raw caoutchouc is very elastic; when cold it becomes hard and brittle, regaining its former condition when warmed. Strongly stretched and suddenly cooled it retains its expanded form until heated to about 95 to 105° F. Fresh cut surfaces remain very adhesive if not touched, and two pieces with fresh cut surfaces can be pressed and easily unite into one piece.

Caoutchouc is not a conductor of electricity, but when rubbed very hard it becomes strongly electric.

It is insoluble in water, but its bulk increases; it becomes lighter in colour, nearly white, and if soaked for a longer period, it adds 25 per cent. to its weight, its toughness, adhesiveness, and elasticity being greatly reduced. Under these conditions the caoutchouc is much more sensitive to solvents.

Absolute alcohol influences it in a like manner, the action being quicker and more intense, especially if it be warmed and raw caoutchouc is used. Rubber adds 20 per cent. to its weight after being left for eight days in alcohol. When taken out it has lost much of its toughness and adhesiveness.

Caoutchouc is affected in a similar way by coal tar naphtha, in which it partly dissolves. The dissolved material is pertinaciously retained by the remainder. If soaked first in

bisulphide of carbon it is easily dissolved in alcohol, but only with difficulty in fatty oils.

Ether, benzin, turpentine, and bisulphide of carbon, also a mixture of bisulphide of carbon and alcohol, dissolve caoutchouc almost completely at the ordinary temperature; at a higher temperature the dissolving process is perfect, but it does not take place without decomposition.

Aqueous vapour softens raw caoutchouc; concentrated nitric acid and concentrated sulphuric acid affect it severely. Concentrated hydrochloric acid as gas or fluid destroys it, but very slowly. Diluted acids and solutions of alkalies have hardly any effect, but a mixture of concentrated sulphuric acid and concentrated nitric acid decomposes the caoutchouc and is very effective.

If it is exposed for a long time to warm air and light, it becomes less elastic on the surface, and a change takes place, apparently caused by oxidation. Spiller states that the affected caoutchouc consists of—

64	per cent.	carbon.
8½	,,	hydrogen.
27½	,,	oxygen.

Whereas unaltered caoutchouc shows the following analysis:—

85½	per cent.	carbon.
12	,,	hydrogen.
2½	,,	oxygen.

Raw caoutchouc heated to 250° F. becomes very sticky, at 360° it begins to melt, and between 400° and 440° it has the consistence of oil and is dark brown in colour. If it is brought in contact with an open flame, it turns dark red in colour, ignites, gives off much soot and a penetrating offensive smell.

By dry distillation the raw caoutchouc gives off gas, water, and also a tar-like body, from which volatile hydrocarbon, caoutchouc oil, and caoutchin can be separated. The boiling-point of caoutchouc oil is from 550° to 600° F., and it is an excellent solvent of caoutchouc and resins. It consists mainly of unsaturated hydrocarbons. Details about the products of distillation differ; they include substances such as sulphurated hydrogen, carbonic acid, protoxide of carbon, hydrochloric acid, ammonia, batyles, caoutchin, enpian, isopra, faradayin, and levein. The curious reaction which caoutchouc shows when brought in contact with sulphur will be referred to when vulcanisation comes under consideration.

VI.—Production of Soft Rubber Goods.

The intention of this book, and particularly of the parts of it still to follow, is in no sense to provide a guide to the processes of manufacture, and still less a handbook for manufacturers. Its object is rather to present a general idea of the manufacturing processes, so that any unskilled person who may take an interest in the subject may form a good idea of the nature, origin and method of collection of the raw rubber, and of how it is treated for use in the various ways in which indiarubber is employed, and how manufactured articles in general are produced.

I.—Preliminary Mechanical Treatment of Raw Caoutchouc: Soaking, Cutting, Rolling (Washing), and Drying.

Crude caoutchouc finds little use in itself. With the exception of cubes cut out of Para biscuits or bottles, for removing pencil and ink marks, or for strips for billiard cushions and square-cut unvulcanised threads, it is seldom to be found in use. All other rubber articles, serving thousands of different purposes, require a more or less long and detailed preparation, and an endeavour will be made to describe the necessary treatment in this chapter.

If the raw caoutchouc were supplied in a pure state, the manufacturer could at once start the manufacture; but this is on the whole not the case, as it happens only exceptionally with some of the Para qualities. All the other kinds are either wilfully adulterated or they have been spoiled by the indifference and ignorance of the collectors, who add impurities and foreign substances, such as water, salt, earth, sand, stones, parts of plants, and other things to the material. These additions are either made when collecting the latex, when coagulating the fluid, during the transport, or when packing the caoutchouc. The necessity arises to subject the material to rigorous manipulations before the production of goods is started, the presence of foreign bodies and other substances being detrimental to the process. Not only does this troublesome but necessary treatment cause much extra expense, but the preliminary manipulations have also an unfavourable effect on the quality of the caoutchouc—lower its resistance and take out of it that much valued "nerve."

The history of the cleaning process is short. At first the caoutchouc was treated by hand work, but this gave very unsatisfactory results. The treatment was soon replaced by

machinery, which gave a more perfectly cleaned material. The preliminary process of to-day, universally adopted, includes the four following methods of cleaning:—

1. Soaking and superficial washing. 2. Cutting in pieces. 3. Rolling or real washing. 4. Drying.

Before describing these four operations of the preparatory work it will be well to consider the proper storage of the raw material. The manufacturer does not generally use up at once the whole stock of material he has bought; he purchases according to the expected requirements, but owing to the fluctuations in price, he is forced to make his purchases at a time which is most beneficial for himself, reaping an advantage which his customers are usually permitted to share. As quantities of rubber have to be stored for this purpose, and as the storage of the material is easily influenced by slight changes, the question of the store-room is one requiring serious consideration.

The most suitable store-room is a fairly lighted, well-ventilated cellar or basement. The individual balls must not be piled directly upon or beside one another; it is preferable to divide each ball by a wall or shelf of stone or wood. If a bag, ball, or other shape is too large, it is well to divide it. Loaves or bottles of about 6½ cubic feet are the largest blocks which should be admitted into one compartment, between each one of which there must be an all-round air space of about 9 to 10 inches. The floor of the store-room should be of asphalt or cement. These precautionary measures are indispensable, and their necessity will be clear to anyone even slightly acquainted with the nature of the raw material.

1. *The soaking or superficial washing.* When the raw caoutchouc is taken out of the store-room it is too firm and hard to be worked at once, even the temperature of our climate being insufficient to give it the required softness. It has to be modified by artificial means. Of all the manipulations of caoutchouc, this is the most simple. The caoutchouc is placed in water heated by steam and remains in this bath according to requirements from 3 to 24 hours. Wooden tubs or iron tanks are most suitable for soaking. The use of acidified water cannot be recommended.

2. *The cutting.* As soon as the caoutchouc is sufficiently soft, the large blocks are cut in square pieces of about 1½ to 2½ inches. The qualities which come on the market in small pieces do not require this treatment, they can be washed as

soon as they are soft. The cutting is often done by hand, when a large knife with a broad and long blade is used. In some factories circular discs and other cutting machines are used for cutting the caoutchouc. The nature of the material is sufficient to point out the need of sharp knife blades for this work, and it is well to continually moisten the blades with cold water as this renders the cutting easier.

3. *Rolling or washing.* This is the most important of the treatment which the caoutchouc has to undergo during the cleaning process. The soaked and cut caoutchouc is placed

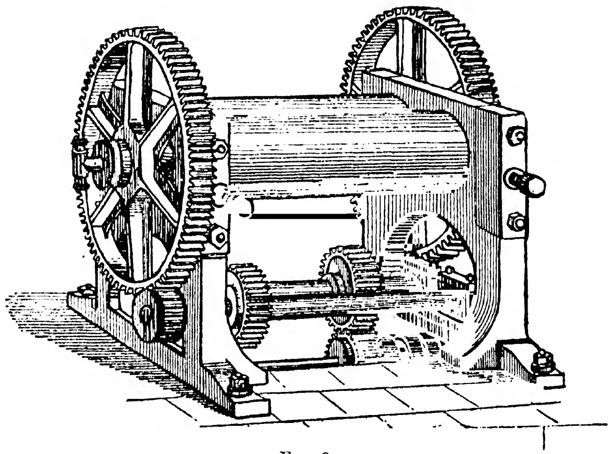


FIG. 9.

in very strong rolling machinery, which removes all contained foreign substances. The ancient methods and machinery used for these, such as stamps, planers, and pulpers, are obsolete and need no description. The method first introduced by an English manufacturer, which employs a rolling mill for purification, has been nearly universally adopted, whereas hollanders and other machines are only adopted for particular qualities of raw caoutchouc. The mill consists of two heavy cast-iron cylinders resting horizontally side by side and revolving inwardly at a different speed. The surface of the cylinders is either channeled, *i.e.*, has longitudinal grooves, or it is flat; but the position of the cylinders remains always the same. English and American manufacturers prefer the channeled cylinders, the channeling making the cleaning much easier, the ribs entering deeply into the caoutchouc and demolishing all foreign substances. Sometimes one of the cylinders of the same mill

is channeled and the other one smooth. The two cylinders rest, as shown in the illustration, in a strong iron frame. The two bearings of the rear cylinder rest slantingly against the frame, and the bearings of the front cylinder rest against two screws. The cylinders are usually driven by gear wheels in connection with the main shaft, which is placed under the floor. Each one of the cylinders receives the power individually, but there are also rolling-mills in which one cylinder drives the other by its rotation and without gearing. The cylinders always revolve inwardly. The screws on the front part of the roller frame serve to bring the cylinders closer together or to separate them. Underneath the cylinders is a sheet-iron tank covered by a perforated plate. Over the point of the two cylinders, where they touch, but about 18 to 25 inches higher, is a pipe perforated at the lower end; this pipe keeps up a continual supply of cold water, which runs off through a pipe connected with the under tank.

The caoutchouc to be washed is placed by hand and in small quantities (according to the power of the rolling-mill) between the moving rollers, at the same time the water-supply tap is opened. The caoutchouc is gripped by the rollers, kneaded, stretched, and torn to pieces. The water pours into all open spaces, clearing out the bark, fibres, and other earthy substances, and removing also all foreign material, which has by this time been finely ground. After the caoutchouc has gone several times through the rolling-mill it has become a long blotting paper like product, the surface of which is like a shrivelled leaf having numerous small eruptions which are separated by little holes; this gives the cleaned caoutchouc its characteristic appearance.

Each washing-mill, just like the mixing-mills to be described later, is served by one workman. The handling of the machinery is not free from danger, the slightest inattention may lead to the fingers being caught between the rollers when nothing can prevent the hand and arm being dragged after them before the mill can be stopped. Good and instantaneously acting disengaging gears are essential on all these mills and must be insisted upon. The washing- and mixing-mills used in the works of the author have a safety gear for disengaging, as shown in the illustrations 10*a* and *b*, where the construction is clearly indicated, but a description will, at this place, be specially suitable. This disengaging gear has the advantage of permitting the workman, by means of a simple pull on a rope,

to shift the gearing instantaneously and bring the mill to a stop, even if one hand has already been caught by the rollers. In the improbable event of the workman's two hands being entangled by the rollers, provision has also been made; the man only needs to throw the weight of his body on the line to disengage the gear in a moment. The construction and working of the gear is as follows: The rope F is carried from one position over the rollers to the other and finally stretched; it is then passed over the pulley G to the ratchet J; the latter has a notch which closes the lever by means of the counter-weight K. If a sudden disengaging of the gear is needed, the workman only requires to pull the rope F, when the ratchet J is pulled up, setting the counter-weight K free. K falls, and the piece M in firm communication with the lever moves upwards, slips along the friction coupling, and moves the disengaging gear to the left. The mill stops in a moment. To engage the gear the following simple method is all that is required:—The lever carrying the counter-weight K is lifted by the attached rope, when the ratchet J moves back and the disengager L moves towards the right.

The size of the washing-mills varies very much. In most cases the rollers are 22 to 36 inches long and of a diameter of 15 to 18 inches; in these cases the speed of the revolutions of one roller is generally between 8 and 12 and the other 3 to 4 turns. American builders in later years have tried much larger mills.

In most of the factories washing-mills can be found which have no massive cylinders, as these are hollow and so constructed as to be heated by steam. They serve two purposes, but this point will be gone into later on. This construction is not suitable for large rubber works, and is not to be found in a well-appointed factory.

All caoutchouc qualities cannot be washed with the same facility. Para washes best and quickest, as it contains the least impurities. The so-called fatty and pitch-like qualities of caoutchouc yield their foreign substances only with difficulty, and very often it is impossible to free the balls from their firmly adhering impurities. Caoutchouc, which is very dry by nature, cannot always be rolled into sheets, as it sticks firmly together at times, and often comes out of the mill in small pieces.

If the washing has been done thoroughly, the sheets are free from foreign substances, except water; and, to rid the caoutchouc of it, the last manipulation of the preparatory work—the drying—has to be undertaken.

4. *Drying.*—To dry the caoutchouc, the washed leaves or flaps are hung on wooden poles or iron wires, or laid on kilns either in drying rooms or in the fresh air; if the kilns are in a drying room, the uniform temperature should be kept between 120° and 140° F. This process is very simple, and hardly needs any consideration. Fatty and pitch-like sorts require a lower temperature, as a high heat renders their defects still more obvious. Then, again, the sheets would drop in pieces on the floor, and roll up into lumps from which the water would hardly find an easy escape. The less adhesive kinds of caoutchouc, which come out of the washing-mills in pieces, are best dried in frames with meshes too close to allow them to fall through.

It is important in connection with the drying that the drying-room should be more or less exposed to the fresh air. A good draught of air quickens the process considerably; in the summer the drying takes a few days only, but in the winter it requires more time, and steam heating has to be resorted to to add to the despatch of the drying. The bad influence of glaring light on caoutchouc has already been mentioned; a dark drying-room is the best. The drying of the leaves in a vacuum has recently also been adopted.

As soon as the caoutchouc is dry, it is taken off the poles or lines and folded like linen, or it is rolled up into parcels. The material is then transferred to storage rooms erected for the purpose, where the caoutchouc is protected from light and air until it is used for the manufacture of goods.

The washed and dried caoutchouc has lost a part of its weight. The difference between the total of the moist and the nett weight of the dried and purified caoutchouc is the "loss in washing." This loss fluctuates very much, and it varies in the different qualities and different harvests. The inferior kinds lose sometimes up to 60 per cent. of the original weight; the better qualities suffer a loss on the average of from 15 to 20 per cent., and seldom more.

It is difficult to put the loss of washing in correct figures, as it is not unfrequent that two deliveries of one and the same quality of caoutchouc give, on washing, quite different results. Henry C. Pearson states in his excellent book on "Crude Rubber and Compounding Ingredients" (New York, 1899), the following average losses, and the results of his investigations and the author of this book's investigations are stated in parallel lines in their percentage:—

	Loss in Washing. Pearson. Per cent.	Loss in Washing. Clouth. Per cent.
American Qualities—		
Para, fine	15 to 20	18 to 20
,, Negroheads	...	40
,, Matto Grosso	...	28
Virgin Para	..	38
Mangabeira	20 to 35	40 ,, 42
Brazil sheets	...	33
Caucho	20 to 40	37 ,, 42
Mollendo	...	14
Cameta	...	37 ,, 42
Peruvian scraps	...	25
Santos	...	28
Central America	20 to 40	...
African Qualities—		
African, without giving the specific origin: tongues	18 to 25	...
African, without giving the specific origin: flakes	25 ,, 35	...
African, without giving the specific origin: thimbles	15 ,, 35	...
Accra	20 ,, 40	...
Bissao	...	35 to 43
Gambia	...	30
Rio Noumez	...	35
Canakry	...	36
Calabar lumps	...	36
Casamance	...	52
Leone Niggers	...	35
Bassam	...	30 ,, 36
Cape Coast, Saltpont, Addah, Quittah, Axim: buttons	20 to 30	40
Cape Coast, Saltpont, Addah, Quittah, Axim: biscuits	20 ,, 30	35 ,, 42
Cape Coast, Saltpont, Addah, Quittah, Axim: flakes	30 ,, 35	niggers: 48
Cape Coast, Saltpont, Addah, Quittah, Axim: lumps	30 ,, 40	...
Cape Coast, Saltpont, Addah, Quittah, Axim: niggers	20 ,, 35	...
Lagos: buttons	25 ,, 35	37 to 45
Lagos: lumps	30 ,, 40	
Lagos: strips	25 ,, 35	
Cameroon: balls	18 ,, 25	35 ,, 43
Cameroon: clusters	18 ,, 28	
Congo: buttons	25 ,, 30	23
Congo: balls	20 ,, 35	
Upper Congo	20 ,, 25	12 ,, 18

		Loss in Washing. Pearson Per cent.	Loss in Washing. Clouth. Per cent.
Upper Congo	red balls . .	18 to 22	...
,, ,,	Lopori . .	16 ,, 22	...
Kassai	black twists .	18 ,, 22	
,,	red .. .	20 ,, 25	18 to 30
,,	balls ,, .	20 ,, 25	
Benguela	sausage . .	16 ,, 20	15 ,, 24
Loanda	niggers . .	18 ,, 20	18 ,, 25
Mozambique	. . . .	10 ,, 35	15 ,, 35
Madagascar	. . . .	25 ,, 55	40
,,	pinky . .	30 ,, 35	...
Majunga .	. . . .	30 ,, 35	
,,	black . .	30 ,, 40	35 to 38
,,	niggers . .	30 ,, 40	
Asiatic Qualities—			
Assam	. . . . .	8 ,, 45	31
,, No. 1	. . . .	10 ,, 15	...
,, ,, 2	. . . .	20 ,, 30	...
,, ,, 3	. . . .	30 ,, 35	...
Penang ,, 1	. . . .	10 ,, 15	30
Java ,, 1	. . . .	10 ,, 15	13 to 23
Borneo	. . . . .	30 ,, 45	20 ,, 55
Ceylon Para	. . . .	...	23
Rangoon	. . . .	...	45
Chinde	. . . . .	...	11
Australian Quality—			
Noumea	. . . . .	...	7 ,, 10

The loss in washing is of importance when fixing the value of a certain caoutchouc quality, but of not less importance is the percentage of resins—*i.e.*, of such substances as can be dissolved in alcohol, acetone, or alcoholic alkali. These resins contain much oxygen, and they are not in reality, as far as can be surmised, original components of the latex. It is much more likely that they come from other saps contained in the plants, and too deep cutting into the stem has brought about the mixing with the latex. Probably these resins come from other plants, and have been carelessly or fraudulently added to the real latex by the collectors. A portion of the percentage of resin is a decomposition product of the caoutchouc. The presence of these resins in the caoutchouc has

only been made the subject of close consideration in later years. It was found that they affected the quality, and it became necessary to fix the quantities contained in the different kinds, as well as to eliminate the substances, so far as possible. C. O. Weber, Rob. Henriques, H. L. Terry and others deserve credit for their work in this direction. In the laboratory attached to the factory of the author of this book many similar experiments and tests have been made.

A definite statement of the resinous substances in the different qualities cannot be made since, as has already been mentioned, it depends on circumstances, just as in the fixing of the losses in washing. Pearson states in his book, which has already been quoted, the average resinous contents found in certain qualities. These are given in the following table, with the addition of the results which have been obtained in the factory of the author.

	Resin Contents.	
American Sorts—	Pearson. Per cent.	Clouth. Per cent.
Para . . .	0.60 to 1.14	...
,, fine (according to Weber)	1.30	2 to 2.90
Para, fine hard cure	...	1.90
,, weak fine .	...	2.30
,, seconds .	...	2.50 to 3.50
Virgin Para .	...	3.48
Matto Grosso .	...	5.80
Negroheads .	...	1.36 ,, 1.54 to 1.80
Cameta . .	...	1.18 ,, 1.30 1.70 ,, 2.20
Ceara . .	1.80 to 2.33	...
Mangabeira .	8.43	...
Colombia . .	2.11 ,, 3.40	...
Peruvian balls .	...	3.90
Bolivian hard cure	...	3.09
Mollendo . .	...	2.30 to 2.73
Bahia . .	...	5.86
Santos . .	...	4.67 ,, 7.50
Caucho balls .	...	3.60
,, sheets .	...	7.80
Rio Janeiro (according to Weber) . .	5.20	

	Resin Contents. Pearson. Per cent.	Clouth. Per cent.
African Sorts —		
African various	6.71 to 10.60	...
Gambia . .	...	4.57 to 4.74
Casamance .	...	4.32
Bissao . .	...	4.32 ,, 10.20
Canakry . .	...	6.09
Rio Nounez .	...	5.25
Leone niggers (Weber) .	9.70	...
Freetown . .	...	11.55
Accrah lumps .	...	21.90
Bassam . .	...	12.67 to 14.60 to 34.30
Cape Coast lumps	...	10.50 to 24.00
Addah niggers .	...	3.26 ,, 5.37
Lagos . .	...	8.60 ,, 9.20 ,, 10.30
Brown niggers .	...	3.56 ,, 4.20 ,, 5.40
White ,, .	...	4.00 ,, 5.46
Benin ,, .	...	3.12
Loango balls .	...	15.20
Mayumba . .	...	24.80
Congo . .	...	12.10 ,, 15.56 17.70 ,, 29.70
Upper Congo .	...	16.50
,, ,, Djuma	...	4.23
,, ,, Lac Leopold . .	...	19.60
Kassai . .	...	1.74
Loanda . .	...	3.60
Mozambique (Weber)	3.20	6.32 ,, 8.00
Madagascar ,,	8.20	...
Zanzibar . .	...	4.30 to 7.81 to 8.76
Asiatic Sorts—		
Assam (Weber, 11.30 p.t.) .	4.88 to 6.45	9.01 ,, 9.37
Burma . .	5.20	...
Chinde . .	...	5.50
Rangoon . .	...	5.04 ,, 7.4
Ceylon Para .	...	1.51 ,, 1.80

	Resin Contents.	
	Pearson.	Clouth.
	Per cent.	Per cent.
Java . .	...	6.18
Penang . .	...	6.80
Tonkin . .	...	6.50
Australian Sort—		
Noumea . .	...	4.74 to 5.47 to 5.98

2.—Treatment of the Washed Caoutchouc.

After the washed caoutchouc sheets described in the previous chapter have been thoroughly dried, they have to pass through

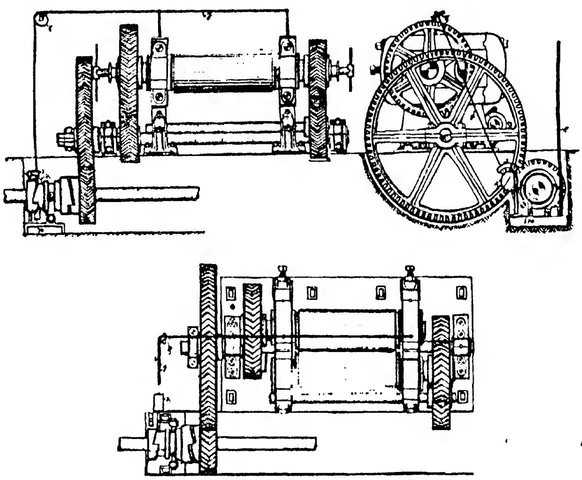


Fig. 10.

another rolling-mill, but this time without the addition of water. The cylinders of the rolling-mill are hollow and heated by steam, the machine is used either for kneading or mixing the caoutchouc or for both operations at one and the same time, and even for either work the same kind of mill is employed. The apparatus consists of two counter-revolving cylinders, generally about 24 to 40 inches long and 16 to 20 inches in diameter, though at the present time larger diameters are also in use. As a rule the cylinders rest side by side. The arrangement to have one over the other is the exception and quite out of date. In other particulars the construction is nearly the same as the washing-mill but channeled cylinders are

attached. The illustration (Fig. 10) is a drawing of the mixing-mill used in the Rhenish rubber goods factory of Franz Clouth at Cologne-Nippes, and gives views of the machine from the front, from the side, and from the top. The instantaneously acting disengaging gear, already described, is also shown.

The treatment of raw caoutchouc for all manufacturing purposes is the same up to this point, but now the use for which it is intended begins to have an influence on the proceedings. Pure unmixed blocks of rubber for fine-cut sheets have to be treated differently from a mixed material; in the former case the rolling-mill serves only for kneading the material, whereas it adds mixing to its functions where the latter class is concerned.

For the manufacture of fine-cut sheets (French, "Feuille Anglaise," and German "Patent Gummi"), which as a "half-product" are an important trade article, only the very best Para caoutchouc should be used. The washed and dried sheets come without any addition to the kneading mill, where they are treated until the whole material has become a homogeneous substance free from air bubbles and comes out of the mill in the shape of rolls. These rolls are exposed to a very high pressure in a hydraulic press, which presses them into fairly large and very homogeneous blocks, which are left for months in a changing temperature, but it is of importance that they should at least once be thoroughly frozen as this makes their composition more firm and improves the quality. In former years the blocks were kept for one or two winters, but nowadays the same effect is produced by the machines. To cut these blocks they are placed and fastened on a horizontal moving slide, which brings them (in a continued downpour of cold water) against the sharp edges of the knife blades, which move with a speed of about 800 to 1,000 times per minute, each time cutting thin sheets up to one-sixth of an inch. Artificial cold and refrigerators are also used in this process, as the blocks cut better when they are frozen than warm. The sheets show on the surface the cutting lines of the knife. The finer or coarser lines of the sheets are caused by the quicker or slower movements of the slide and the movements of the knife. As soon as a sheet has been cut, the block is lifted by means of a spindle screw, and the lift is automatically adjusted by the thickness of the sheet; the rubber block always comes back to the right position to face the knife.

Another method of producing fine-cut sheets is also much in use. The purified caoutchouc is put in a hollow vertical cylinder where it is pressed by a close-fitting piston working under a high pressure. This method produces cylindrical blocks, which are also cut in sheets by means of knives, but in this case the knife is carried in a tortile line from the periphery of the block to its axle.

A third method, but one which does not improve the quality of the rubber, is to make the sheets, not out of blocks, but from carefully cleaned Para caoutchouc which has been rolled in a heated calender. The material produced by this process cannot be compared with the qualities which have been mentioned. To make this quality look like the best material, the sheets are impressed by the cylinder rolls with imitation cutting lines. The imitation is perfect, and it is regrettable that the buying public, which takes the cutting lines as a hall-mark of the quality, should thus be misled into purchasing and paying for material which only represents, but is not, what is required and what has been asked for.

The production of fine-cut sheets was invented by Mr. Charles Mackintosh, and for a long time the firm of Charles Mackintosh and Co. had a monopoly of the business. Later on sheets were also produced by other English manufacturers, soon followed by French competitors, and during the last ten or twelve years they have also been made in Germany. The sheets are often coloured by the addition of chemicals, and red and green sheets can be obtained. The green sheets have nearly disappeared from the market, and even the red are not much favoured, as the natural-coloured brown and black material is superior in quality.

The customary trade thickness in which these sheets are sold on the market is numbered by the following scale :—

$$\frac{1}{4.15}\ \frac{2}{3.26}\ \frac{3}{2.58}\ \frac{4}{2.35}\ \frac{5}{1.85}\ \frac{6}{1.66}\ \frac{7}{1.40}\ \frac{8}{1.14}\ \frac{9}{0.96}\ \text{millimètre.}$$

$$\frac{10}{0.83}\ \frac{11}{0.62}\ \frac{12}{0.54}\ \frac{13}{0.44}\ \frac{14}{0.41}\ \frac{15}{0.37}\ \frac{16}{0.33}\ \frac{17}{0.20}\ \frac{18}{0.18}\ \text{millimètre.}$$

To prevent the sheets sticking together after they have been cut, either when in stock or on their way to the customer, it is necessary to rub them in with a solution of soap and warm water, which forms a fine soft film as soon as it is cold.

Until a few years ago adulteration of fine-cut sheets was not known and the quality was always unsuspected. Since then a great change has taken place, and either from fraudulent motives or to enable the cutting of prices, sheets have been sold on the market and have been used for manufacturing goods which contain about one-third of adulterating substances.

The pressed blocks can be cut in square threads just as well as in sheets, and by the same method; these threads were formerly often used in an unvulcanised condition. But little use is now made of the material, since unvulcanised caoutchouc becomes bad when the temperature reaches freezing-point, or sticky when it goes up to 100° F. Threads which have been treated with sulphur and vulcanised have supplanted them.

If it is desired to make mixed material of the washed raw caoutchouc it must be softened in the heated kneading-mill to make it amenable for the addition of the ingredients. The addition takes place in the kneading-mill, which serves now its double purpose as kneading and mixing apparatus. A Frenchman humorously described the production of caoutchouc as "the art of adding cheap substances to the material without greatly impairing its specific properties." To be just he ought to have added, "to make it useful for the many requirements, or to cheapen it." It is doubtful if there exists another material in the industrial world which responds to manipulations to such an extent as caoutchouc, and from which so many varying qualities can be produced. To paraphrase a saying of Heine, "Caoutchouc has more talent than character." The additions consist of sulphur, as far as it is needed for vulcanisation, and of other substances. The eventual use of the particular quality may need the addition of foreign substances of a degree of hardness, toughness, colour, etc. The price of the goods is so low that the use of expensive material has to be reduced. The ingredients chiefly added to caoutchouc are litharge, zinc-white, white lead, chalk, barytes, metal, soot, asbestos, ground hemp, and a few others less frequently used, such as glass dust, fine sand, etc.

It is undoubtedly a fact, and also a great pity, that the quality of the products of the rubber industry has deteriorated from year to year. It will therefore be not uninteresting to investigate these remarkable symptoms. In the first place must be mentioned the inconceivable but undoubted ignorance of the consuming public regarding the origin and the nature

of the raw materials used for rubber-goods production. Whereas every educated layman has a proper knowledge of most industrial pursuits, such as the production of metals, cement, glass, textile and pottery products, and also of the nature of the methods and the use of the employed raw materials, it is an undeniable fact that even engineers, technical men, and chemists, in whose work and undertaking the products of the caoutchouc industry play an important part, know very little about the subject. Often they cannot distinguish gutta-percha and caoutchouc, soft and hard rubber, and it has happened that they have mistaken heterogeneous materials, such as animal glue, for caoutchouc. About the raw material and its origin the knowledge seldom extends further than that Brazil supplies the best rubber through the shipping port of Para, and the best quality is therefore called Para. Of the large number of Para sorts and their distinction nothing is known. A similar ignorance exists with regard to the methods of production of goods; some have an idea that rubber goods are moulded or cast in the same way as metal or plaster. It is therefore no matter for surprise that quality cannot be judged accurately. It is difficult to judge the quality, as colour, smell, and specific weight are not reliable points for fixing it; the quality depends in the first place on the kind and the origin of the raw caoutchouc. The kind and origin cannot be fixed in vulcanised rubber, not even by chemical analysis, as this can only give the approximate percentage of the materials in the mixing but cannot fix the quality.

Considering the difference that exists between the rubber from each of the principal caoutchouc-yielding trees, and also the fact that each of these kinds is split up into many subdivisions (the difference in the price, running from 2s. 10d. to 6s. per lb.), it is perfectly clear that the divergence in quality can be enormous, and that only the manufacturer himself can judge the value of a certain quality.

If the expert meets with difficulties in judging the quality of caoutchouc for certain purposes, how little can the greater part of the consumers know anything, lacking as they are in experience and knowledge, of the fundamental principles that guide decision? The impossibility of judging the quality is thus obvious, and it has created a certain carelessness which again has led to the belief that quality has no effect on rubber goods, and that the inferior article is equal in use, for which reason

cheap products receive a preference. The humour of the situation is created when the inquiries and orders for goods arrive, "first quality" being always insisted on, but expected at the lowest price.

The manufacturers were unable any longer to hold out against the desire for cheap goods, and although they recognised the danger of continually lowering the quality, and produced the best goods in their power, little by little they yielded to the clamour, and began to produce the demanded goods at cheap prices.

Probably over-production (to a higher degree than the desire for reduced prices) may account for the cheap qualities, since forced sales threw goods at any price on the market, others having to follow as best they could, and by making cheap goods to retain the customers. Fifteen or twenty years ago Germany had only a limited number of rubber works, equipped with sufficient capital, which had slowly worked themselves up to good positions and great prosperity, which was expressed in substantial dividends. Encouraged by these dividends a large number of factories were started without sufficient financial means or little practical experience. These, in order to get a sale for their goods, began to undersell. It is self-evident that these prices could only be accepted by a reduction in the quality, and as soon as the old established firms supplied better goods for the same price these manufacturers had to further reduce the prices of their goods to keep their place in the market. Thus quality and price went step by step still lower and lower.

Even worse price cutters than the manufacturers are the wholesale dealers, the medium between manufacturer and retailer, who often compete with the manufacturers and take the orders at cheaper prices than the manufacturers can supply, giving to their customer, quite naturally, an inferior quality. These methods open the road to reductions in price and declining qualities, and mainly responsible for this is the ignorance of the purchaser, who cannot distinguish between good and bad products. A well-known and natural consequence has been that goods could be purchased cheaper from second and third hands than from the manufacturer directly.

In spite of their inferior quality many of the firms sold their products as "first quality," and this can partly be excused, because nobody can say what it means, as the first quality of

one sort may be second or third quality of another. To call all sorts by the same name can, however, only lead to a still greater confusion amongst the consumers, who do not know how to fix their standards. But it is to be severely condemned, and can only be called fraudulent, to describe inferior qualities as "Para," as too often happens. Only such sorts have a right to this designation in whose production only a "fine Para" caoutchouc has been used, other sorts having been strictly excluded.

A no less remarkable phrase than the repeated description, "Para," for goods which are made of other caoutchoucs, is the appearance of fantastical and fancy names given to certain mixtures to make the consumer believe the material to be something quite new and abnormal. It is incredible and humiliating how the consumer can be misled by a name and can be brought to buy the goods, thinking he is purchasing something quite extra, whereas the product with the fine name is a cheap article sold at a good price.

The deplorable deterioration of the quality of rubber has thus its explanation on the one side in the ignorance and the impossibility of judging the quality by the consumer, followed by continual reduction in price. On the other side there is the over-production by the manufacturers, causing the less prosperous concerns to reduce prices to obtain orders, followed by disastrous competition between manufacturer and dealer, the intention of the latter being to undersell the former, and this naturally leads to a demand for cheap goods of bad quality. The prices of raw material have risen during the last years, but the price of the finished product has not kept step by reason of a false regard for the customs of the public. The only salvation lies in the formation of trusts (Cartels), but they also have their seamy side, a fact which cannot have escaped those who have given them any attention.

To colour the raw material, not only zinc-white, etc., but also vermilion, red lead, ochre, ivory black and soot are added. The recipes for the particular mixtures, which depend on the choice and use of the right qualities of raw caoutchouc, are innumerable, and countless qualities of vulcanised rubber can be produced. Each recipe is carefully guarded as a precious secret. Only an absolute knowledge of each ingredient permits a particular quantity to be reproduced, as chemical analysis—as has already been stated—will in most cases not give a suffi-

cient clue to the additions made and the quantities used. Even practical tests and researches do not lead to the speedy discovery of an approximate and successful result.

The manipulations of kneading and mixing are very simple; the construction of the apparatus and the nature of the material to be handled explain them easily. After the stated quantities of raw caoutchouc—which does not need to be always of the same quality, and generally is of different origin—and the other materials have been carefully selected and the weight noted, they are placed in small portions between the rollers. The larger part of the material becomes at once a plastic substance, which either sticks naturally to the roller and is carried round with it, or if this is not the case, the material has to be brought up from the bottom of the mill to the rollers. A loose cover to the first roller is soon formed, and as long as the machine is kept going it is pressed between the two cylinders. If some of the material drops down or does not adhere it is brought back until the whole of the mixture has become one homogeneous mass. As soon as the well-mixed loose cover has gone several times through the rollers it is ripped open with a short sharp-edged knife, rolled in cylinder shape, and again placed in the rolling-mill. This manipulation is repeated until a uniformly kneaded and moulded material can be finally taken off in the above-described fashion.

The rolling-mills are not always open, several constructors place the cylinders in a wholly cased-in tank. The reason for this is to prevent pieces of material falling, and to save the work of the attendant. Theoretically this construction is quite correct, and much can be said for it, but practically it has not proved of value, at least not as far as caoutchouc is concerned. Gutta-percha manufacturers make use of it, but the material is different, as will be shown in another section of this book.

The rolls of rubber are taken off the cylinders for further treatment on a calender, where they are rolled into thin sheets. These calenders have generally a system of three and sometimes four rollers. An English manufacturer designed and constructed a calender with six rollers, but it did not meet with the expected approval. The illustration shows a calender with four rollers. The calender rollers are generally of steel, hollow inside and heated by steam. The cylinders can be moved, by special means, to enable the making of sheets of all sizes, but it is seldom that a factory produces any sheets of more than one

to two millimètre thickness. The temperature of the calender rollers is of the greatest importance as regards the equality of the sheet, the prevention of stripes, so called flowers, and air bubbles. Each roller has on its axle not only a steam, but also a cold-water pipe, as well as a third pipe which carries the steam and cold water off. The sheets which leave the calender on the opposite side of the point where they are introduced run

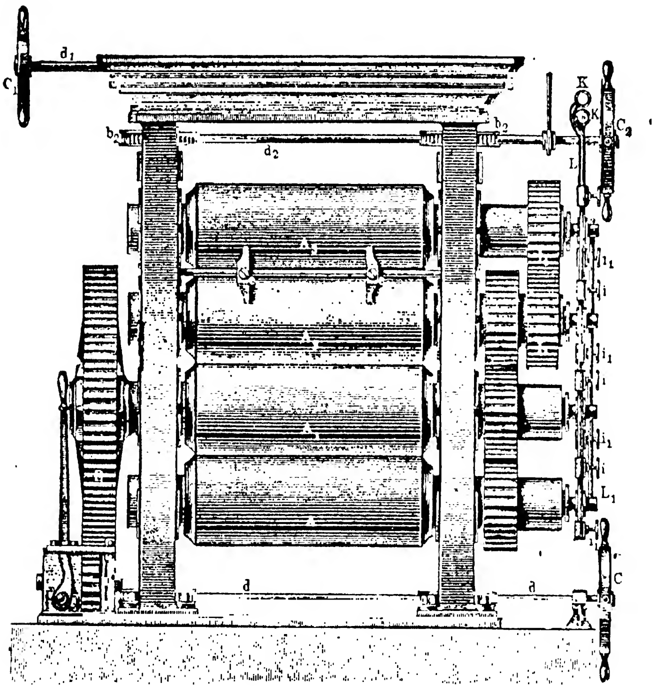


FIG. 11.

on to a horizontally stretched cloth, and to prevent sticking them together they are rolled on wooden cylinders.

The fine-cut sheets are prepared with their imitation cutting marks on calenders of the same construction, which have for this purpose a steel or bronze cylinder with engraved channel on the lowest roller.

3.—Production of Goods from Soft Rubber.

The production of rubber goods, with the exception of the making of waterproof tissues, is in reality a truly plastic work, the larger part of which has to be done by hand. Real machinery has little to do with it, but many, and the most divergent forms of moulds and presses are made use of.

The foundation for all the work, again, with the exception of the production of waterproof cloth, is always the cut, rolled, pure or mixed sheet.

Owing to the ease with which the cut sheets can be used for further production, even by the employment of the most primitive methods, they found widespread acceptance in the early history of the rubber trade. The production of cut sheets soon developed in Germany and France into a branch of the caoutchouc industry by itself, but this speciality has never been considered as a great one, and the largest rubber goods manufacturers have never taken it up, or have done so only as a side line. The industry has in many cases become a home trade, and this is specially the case in Manchester and Paris. The best-known and most used articles made of fine-cut sheets are outfits for feeding-bottles, tobacco pouches, tubes and pipes for chemical laboratories, and the many articles for surgical and technical use, for which no other caoutchouc material serves so well as the one at present under consideration. The manufacture of all these articles is done by hand, and is very simple, because the freshly made surfaces caused by a cut with a knife, a die, or a pair of scissors easily adhere to each other, and this adhesive property can be increased by a slight moistening with benzin or a solution of caoutchouc. It is only necessary to cut the parts of these articles according to a pattern, an easy work for a knife or a pair of scissors. Articles made in large quantities, like outfits for feeding-bottles, can be stamped out in parts, and assembled or put on forms to give them the required shape. The portions forming the surface parts are either stretched with a paper-knife or slightly tapped with a little hammer, the head of which is rounded off. The hammering is done on a piece of iron with an equally rounded surface. Hollow articles like balloons, tubes, etc., are strewn with talc on the inside to prevent the sides sticking together. The vulcanisation of these articles, of which a detailed account will be given in the next chapter, is equally simple.

Much more complicated is the working of the mixed sheets,

and this is partly caused by the larger and often very extensive dimensions which they assume. In the first place, goods for technical use, such as packing, cords, valves, hose, beltings, roller covers, etc., have to be taken into consideration. It is in the nature of the use of many of these articles that they should have the elasticity from one side to the other, or from top to bottom, or in a vertical direction, or lateral, in a horizontal direction, or, for hose, over the whole circumference. This is best done by the insertion of tissues of metal, cotton, or linen, and a distinction has to be made between articles with or without these differences.

Sheets without the insertion of textures are the simplest productions. This is a material which has been rolled in the calender to an equal thickness, and cut to a certain length and width.

Flat and circular discs are cut out of sheets by quickly rotating knives; flat rings are made in the same way, only one knife with two blades, one of which is placed on the outer, and the other on the inner edge, is used. Larger quantities can be quickly produced by placing several sheets one on top of the other, when equal sized discs or rings are easily produced. Rings can also be cut out of cylinders or tubes which are placed on a wooden spindle, when the cutting off is easily done.

Plain cords or ropes without insertion, round, half-round, three, four or more cornered, of the most varied profiles can be pressed by machinery. The prepared material, brought to the proper temperature, is forced by a stockworm to an opening which can be altered to any desired diameter, and through which the material is pressed, coming out at the other end as perfected rope of any shape or size. Cords are also often rolled out of fine-cut sheets.

Plain tubes or pieces without insertion, at least such of smaller calibre, are made by the same machine by inserting a core in the round opening, the diameter of which equals in size the required inner diameter of the tube, whereas the whole opening is the same as the outer diameter.

Thicker discs or valves are cut to the approximate dimensions and inserted in iron moulds. The moulds are shaped exactly to fit the finished article, and when these are vulcanised, the whole is put under very heavy pressure. The production of other formed or moulded articles, such as buffers, stoppers, billiard cushions, mats, is done by the same process. These

moulds are often very complicated, and form a considerable portion of the cost of the article; it often happens that the mould is much more expensive than the article, and this is especially the case if only a few specimens of the same kind have to be produced.

Hollow articles, such as pouches, balloons, toys, dolls, etc., are cut and assembled in the same manner as described for fine-cut sheets. Before closing, a little water or carbonate of ammonia is poured in. They are placed in their moulds, and in these they are vulcanised. The enclosed air, which expands in the heat, or the developing gases and the steam formed by the added fluid, forces the material firmly against the mould, and the whole is well pressed into all nooks and corners.

It has already been stated that for several reasons many articles require a filling of cotton, hemp, or wire mixture. All these filling materials have to be coated before the manufacturing can be undertaken. They are drawn, tightly stretched, through a calender, which brushes a heated and soft film over them, or a workman brushes the material with a solution made of caoutchouc in benzin.

Sheets with stiffeners or insertions are worked on the calender, and the process is similar to the coating of the inserted material, with the difference that it is prepared instead of raw material which is treated, and that the rollers are set to fit the thickness of the rubber layers and the texture which have to pass through them. The material has to pass the calender once for every added layer of rubber. If the material has one insertion it passes the calender rollers twice, and with two insertions the process has to be gone through three times.

Tubes, piping, or hose, with or without textile insertions, are stretched over metal tubes as soon as their diameter has reached a certain size. The process is as follows: the sheets are cut in small narrow strips, and these strips are alternately with the inserted materal laid round the metal tube, until the rubber pipe, tube, or hose has the desired thickness. England, America, and Germany employ machinery for making these tubes, and these are especially useful for the smaller sizes. Some tubes have a spiral wire between the rubber and the insertion, which is worked in with the other materials. Tubes and hose constructed by this method are generally vulcanised on the metal tube on which they have been manufactured.

Cords or ropes with insertions are (if it is desired that they

should be round) rolled up from coated texture, strips, and sheets; in case a square shape is desired, such as for packings and tuck-cord, the material is wound round a four-cornered core and pressed in a mould.

Driving belts, which require the best and strongest cotton texture as insertion, are placed together according to the required width and thickness, for which a varied number of layers is necessary. These are generally sewn together longitudinally to give the whole material a firm grip. When this has been done, and after they have received a rubber coating enclosing the whole, as in a case, the belting is placed in a mould and pressed.

Covers for cycle tyres (during the last few years an important part of rubber goods manufacture) are pressed as already formed covers into the moulds, or they are built up flat on a drum from strips or ribbons.

Covers for automobile tyres are only made in special moulds; their calibre is too heavy for the ordinary process.

Roller covers, when they are not to be vulcanised on an axle, are made of thin sheets in a similar way to tubes made over a spindle. But when the covers must adhere to the axle, the sheets are laid on the axle and pressed into one homogeneous cover. To fit the cover securely it is necessary, if soft rubber has been used, to insert between it and the axle a layer of hard rubber.

Considerations of greater durability, or special requirements, make it sometimes necessary to combine the use of soft and hard rubber, as in the case of rollers for wringers, covers for rollers for paper factories, the lining of acid pumps, the linings of bottle-cap apparatus and others, but of these more will be said later on.

A singular product is the so-called spongy rubber or fungous caoutchouc. It is produced by quickly heating a solution of rubber in a volatile reagent. As the reagent is vaporised it leaves a porous mass of solid rubber. This spongy or moss rubber is mainly used for toilet articles, such as bath sponges, friction brushes, glove cleaners, as insertions for several medical instruments, and for soles for brewers' and hunters' boots. Owing to its material and production it is, comparatively speaking, not very durable, and it soon becomes hard and brittle. The importance of the product to the trade is therefore small.

4.—Production of Waterproof Textures.

Two well-known methods for manufacturing waterproof textures are known: the so-called "double textures" and the "single textures." The former consist of two layers of the same or different material, which adhere to each other by means of a thin layer of caoutchouc. The latter, the single textures, consist of a single textile material, which is sometimes coated on one side only, and sometimes on both sides. The extremely widespread use of these water and air-proof materials for garments as a protection against rain as well as other fluids, dampness, etc., for diving dresses, tents, transportable air-filled boats, bathing tubs, balloons, cushions, mattresses and beds, as waterproof sheets for sick and children's beds, and a thousand and more requirements, is very well known.

The composition of the double textures has already been stated. The single textures are now manufactured by the following process: the caoutchouc, often mixed with colours (black, white, ochre, also red, yellow, and brown), is dissolved in turpentine oil or benzin, and forms a sort of dough or varnish. It is brushed over the textile material by means of a specially constructed machine, the spreader. These brushings or spreadings must be very fine, and after every drying the process has to be repeated six to twelve times. One of the first requirements of a good caoutchouc coating is the equality of the spreading and the absence of little knobs. Double-faced material is made by treating the texture on both sides in the same way.

The spreader consists of a horizontal roller resting on an iron frame; the roller is fixed on the upper end of an iron table provided with hollow, steam-heated plates. Over the roller is a blade with a somewhat blunt edge, regulated by spindles according to the required thickness of the caoutchouc layer. Between the roller and the blade the texture to be treated has to pass, and the caoutchouc solution is applied to it by means of spatulas just before it reaches the knife. The coated texture has to pass the heated table on the other side, and on the way most of the benzin contained in the solution has volatilised. The material is rolled on a cylinder on the lower end of the table, and when the whole piece of texture has been brushed or spread it is brought back to the front of the spreader, and the process renewed until the coating is sufficiently thick.

The experiment of using the fresh caoutchouc latex as it

comes from the tree, and spreading it over the texture, has not had the desired results, not to speak of the many disadvantages and inconveniences of transporting the latex from over sea to our shores. The primitive method has been tried, but it has never found an extended use.

After the coated textures have been vulcanised, the now waterproof material is placed in the hands of tailors, who make garments and other goods of it just in the same way as they treat other cloth, with the exception of the seams, which are sewn and solutioned together. Brushing the sides to be solutioned with pumice-stone water before they are thus treated can be recommended. The solution should have time to dry before the solution of caoutchouc is applied to stick the material together. A hand-roller is finally employed for pressing the whole, and to avoid creases.

5.—The Production of Rubber Shoes.

The production of rubber boots and shoes is of the very first importance to the caoutchouc industry. It has reached a great output and the demand is increasing. Large manufacturing establishments make the production their sole business, or they only produce goods in addition to rubber shoes which are somewhat related to that manufacture. The product itself and the methods of manufacture have consequently and naturally been much improved, and it is probable that perfection has been reached. What a difference there is between the clumsy and unsightly foot-covering which, according to Charles de la Condamine, was manufactured and used by the natives of Quito in 1736 (they were made in a primitive fashion of the Hevea latex) and the elegant and glossy boots and shoes turned out by the rubber shoe works of the present time! Every change in fashion is copied, and the product is so light and comfortable that it can easily stand a comparison with the best boots produced from other materials, and in many cases can surpass these with regard to quality and fit.

The manufacturing of rubber shoes at first sight seems an easy and simple task. A light, soft, and somewhat elastic knitted fabric, white, grey, or red (the lining of the shoe), is used to cover a caoutchouc material which has been coloured black. The single parts are cut out to pattern and the different portions are assembled over an iron frame. To give the shoes the required black glaze, the outer side is brushed with lacquer,

and then the shoe is vulcanised on the form or mould. Very simple! But to facilitate the production in large quantities and to preserve the manufactured goods for long wear as desired by the modern purchaser the most complicated machinery is required, and very elaborate and very ingenious manipulation is necessary. Calenders with engraved cylinders are used for the upper part of the shoes and others for the soles; presses for the heels; cutting machines for individual parts, ornamental strips, etc. When the shoe has been finished on its last, it is placed in an air-tight chamber which has been heated by means of a steam-pipe, and here it is vulcanised. Many hundred pairs can be treated simultaneously, and for this purpose they are placed on small trucks which are rolled into the vulcanisation chambers. The vulcanisation is an exceptionally difficult operation, requiring great attention and long experience to be successful.

6.—Production of Threads.

The manufacture of quadrangular threads from washed and pressed caoutchouc blocks has already been mentioned, and it was stated that this method has long been discarded. The ancient method of making round threads of caoutchouc solution is worthy of mention on account of its historical interest. This method required the caoutchouc to be dissolved in benzin, and the solution was forced through a tin plate punched with holes like a sieve. The fresh, soft threads were carried over an endless cloth strewn with talc, and as soon as the benzin had volatilised (which the length of its journey on the cloth made possible), the threads were reeled up. Very thin threads were made by stretching the fresh, unvulcanised, thicker threads in a temperature of about 240° F., when they were quickly cooled down to about 30° F.

Quadrangular threads, now exclusively in use, can be produced by many different methods. One of the older methods required the stamping out of round plates about an inch thick to discs ten to twelve inches in diameter, in which form they were vulcanised, when they were cut into spiral ribbons, and the latter then divided into threads. A more modern method makes thin sheets (of the thickness of the required threads) from a mixed rubber which contains a good proportion of sulphur. This is run through the spreader on an endless cloth. To prevent the sticking of the sheets to the cloth (which is made from a fine cotton twill) this has been covered with a

vulcanised rubber cover and is continually strewn with talc. These sheets, twenty to twenty-four inches long, are, after vulcanisation, brushed with a shellac solution, rolled on a cylinder, and as soon as the sheets are dry and firmly adhere as a solid material, the whole is cut into threads by means of a knife. They are then cleaned by boiling in a caustic lye and dried. This last process is to remove the sulphur which otherwise would show on the surface (blooming).

Caoutchouc threads are only used for making elastic textures, otherwise they find little employment. As material for elastic textures they are of very great importance; stockings, bandages, braces, garters, shoe elastic, and many other goods are manufactured of them. These are produced on a weaving loom, where the caoutchouc threads are either the warp or the weft. Elastic for shoes is also produced by making two knitted fabrics adhere by means of a very thing caoutchouc layer between, this material being called "patent elastic."

7.—Insulated Wires.

Since caoutchouc has entered the service of electricity and is used, in addition to the more important gutta-percha, for insulation purposes, the production of insulated wires has become the youngest and not the least important branch of the trade. Rubber goods manufacturers have not taken up the article, the production rests mainly in the hands of the electrical cable works, which either purchase the required rubber washed and already prepared for vulcanisation as a half-finished product, or they have installed their own washing and brushing mills. To cover the wires with the prepared material, similar tools and apparatus are used such as have been described for the production of drawn cords and ropes, with the difference that for insulated wires the wire to be covered is made to enter at the rear and come out in front of the apparatus, *i.e.*, the reverse way when compared with the other construction. According to another but less employed method, the wires are covered with thin sheets cut into strips which are rolled round the wire, similar to the rolling of hose round the spindle. Caoutchouc insulated wires are seldom used as such independently. When it is done, the wires are covered with a thin texture of cotton or silk. As a rule a number of the insulated wires are combined for one cable, which receives another independent cover.

VII.—Vulcanisation.

The preliminary treatment of the raw materials and the production of some of the most important articles of the rubber industry, so far as the work of giving them their proper shapes is concerned, has now been thoroughly considered and the stage has been reached where a description of the vulcanisation becomes necessary. This process is one of the most important in the production of rubber goods and may be characterised as the pith of the whole procedure. Before entering into the details it will be advisable to recall some of the characteristic properties of the raw unvulcanised caoutchouc. As has been stated, and it must be borne in mind by the reader, raw caoutchouc begins to soften at a temperature of about 85° F., and when the temperature has reached 120° the material is highly adhesive. It is the reverse when the temperature sinks to about 50°, for then the material is hard and brittle, and when 32° is reached, it appears as if it were frozen. Under the influence of atmospheric light and air, and especially under the simultaneous influence of moisture and heat, it oxidises and becomes a pitch-like, sticky material. It is quite clear that a product which can be affected and changed by the action of temperature and natural means, as the raw caoutchouc proves to be, is not a material in a fit condition for the universal and industrial use it has been destined for. It was a problem for the chemists to find means how to eliminate the bad properties and how to enhance those which are so useful. A solution of the problem was found in vulcanisation, which brings about the following effects :—

1. The caoutchouc becomes as much as possible insensible to the *influence of changing temperature* and the action of chemical agents.

2. It loses the adhesive properties and the great plastic-forming capabilities which characterise the raw unvulcanised material. It gains greater elasticity, the soft rubber acquires a greater consistency and greater tenacity, and it resumes at once its old unchanged form as soon as the exterior influences have ceased to act.

This is effected by the combination of caoutchouc and sulphur under the influence of heat.

The French chemist, Anselme Payen, has made interesting

researches in this direction, and he found that a raw sheet of caoutchouc dipped in a bath of molten sulphur swelled when the whole was heated to about 250° F., at the same time absorbing a part of the sulphur. After a quarter of an hour the caoutchouc showed no changes; when touched, it was still as sticky as before. The experiment was continued for thirty to forty minutes, and the temperature was changed to between 265° and 285°, when the caoutchouc became yellow, losing its stickiness. The elasticity had increased, and the effect of cold was entirely negative. This result was obtained when the caoutchouc had been mixed with flowers of sulphur, and was exposed for the same time to the last-mentioned temperature. Each degree of temperature between the melting-point of sulphur and 320° F. effects the same results, which were obtained the quicker the higher the temperature rose.

This experiment contains the main outlines of the process of vulcanisation. It is, however, not only pure sulphur which can effect the vulcanisation of caoutchouc; bisulphide of carbon with chloride of sulphur and several other sulphur compounds, iodine, bromine, etc., can act in the same way. In this manufacture only pure sulphur need be considered; only one method—the so-called cold vulcanisation—employs chloride of sulphur mixed with bisulphide of carbon.

It is not intended to give a full description of the numerous trials which were made to find the best mode of procedure, or to write a historical narrative of vulcanisation and its development. It will be sufficient to have a short delineation of the methods in common use, and even these without an attempt at chronological sequence.

Parkes, of Birmingham, invented in 1846 the so-called cold vulcanising method, for which purpose he exposed the caoutchouc for shorter or longer periods (from about one and a half to three minutes, according to the thickness of the goods) to a mixture of a hundred parts bisulphide of carbon and two and a half parts chloride of sulphur. After the pieces had been dipped in this compound, they were quickly taken out and dried in a warm stream of air of about 78° F. temperature; or, to prevent the prolonged influence of the chloride of sulphur, the pieces were washed in lukewarm water, in which the chemical decomposes before the drying begins. Instead of the bisulphide of carbon, this method permits also the use of carefully purified petroleum or benzin, but their usefulness has not

yet found any special recognition. The Parkes method is especially adaptable for the vulcanisation of smaller articles which are not too thick; thicker pieces would have to remain in the bath for a longer period. This exposes them to the danger of burning. Parkes recommended a mixture of half a part of chloride of sulphur and a hundred parts bisulphide of carbon, and the repeated dipping—about two or three times—of the goods to be vulcanised into the bath.

The process does not exclude the danger of many disadvantageous results. Practically the method is only used for manufacturing articles out of thin, fine-cut sheets; it is used on account of the primitive means which can be employed, the quickness with which vulcanisation can be effected, and because it can be so easily adapted to the use of twine workers, who make most of the articles on the market by this method. On a similar basis rests the vulcanisation method by means of chloride of sulphur as vapour. The method is seldom employed, and only for very thin goods.

Hancock's method, the so-called heat vulcanisation, consists in bringing the articles to be treated by this process into a bath of molten sulphur which has been heated to about 284° to 302° F. The goods remain in this bath until they have been thoroughly permeated and have absorbed about 10 to 15 per cent. of the sulphur. Before bringing the articles into this bath, it is advisable to keep them for twenty-four to thirty-six hours in a heated room, to let the solutioned seams (which have been treated with the benzin and caoutchouc solution) become quite dry. If this precaution is not taken, one risks the danger of the seams coming apart. After the articles have been taken out of the sulphur bath, a firm sulphur crust forms on the outside of the vulcanised goods, which has to be removed by rubbing or scraping with a fluted board. The goods are now removed to a room heated to about 85° to 105° F. In spite of the rubbing and scraping, the articles still contain too much sulphur, which comes to the surface when the goods are stretched in the form of a fine grey powder. This can be removed by washing the goods in a dilute solution of soda. This vulcanisation process is used principally for goods made out of fine-cut sheets, and, if properly done, it is in all cases to be preferred to the cold vulcanisation.

According to a method of Gerard, the caoutchouc remains for three hours under a pressure of four atmospheres in a solution

heated to 265°, of penta-sulphide of calcium of 25° B. After the goods have been taken out they are washed in water and dried. This process gives excellent results, vulcanising well and equally all over. The goods have a fine, soft surface, something like velvet, but the method is only suitable for articles of smaller dimensions. To enable manufacturers to use the process for larger articles, Gerard recommended the mixing of the caoutchouc with a fine, pulverised, earthy material, such as hydrate of lime : 100 parts of caoutchouc, 6 parts of sulphur, and 6 to 10 parts of hydrate of lime are carefully mixed in the mixing machine. To vulcanise this material it is placed in a closed steam or water bath at a temperature of 265° F., in which it remains between one and a half and three hours, the length of time depending on the thickness of the goods.

The most important method of vulcanisation, which has found a very widespread use, was invented by Goodyear. It consists essentially in the mechanical mixing of a quantity of sulphur with a quantity of caoutchouc, when both materials are cold, and exposing to a certain temperature under a definite pressure. In French factories for the latter work the term "cuisson" is often used, and some of the German manufacturers call it "burning"; but the universal name for the process is always and everywhere "vulcanisation." This is undoubtedly the proper term, and for this purpose it has found universal recognition. The method is very rational, it works under definite rules, and as long as proper care is taken accidents can almost be excluded. The washed and dried raw caoutchouc is mixed in the mill with an addition of seven to ten per cent. flowers of sulphur, or sulphide of antimony, with equal quantities of free sulphur. It is self-evident that for certain purposes other points have to be taken into consideration, and consequently the addition of sulphur may vary from three to fifteen per cent. A fundamental condition for good results is a very careful and equal mixing; the material must, in fact, be absolutely homogeneous. Under this condition and when the material has been moulded or given its proper shape, it is placed in closed chambers where it is exposed to a temperature of about 265° to 300° F. These walled-in chambers are at the present time very seldom used and only for certain purposes. Closed iron boilers, in which three to four atmospheres of steam can be introduced, have taken their place. In addition to these boilers presses are used equally often, the

plates of the presses being also heated by steam. The construction of these presses and boilers will be referred to later, when several other appliances come under consideration.

Two or three hours are enough to give the goods a sufficient vulcanisation by the employment of this method. The goods vulcanised according to Goodyear's method suffer from the same bad effects as those described under the Hancock method; a fine grey powder is formed on the surface as soon as the goods are pressed or stretched, even after a certain time of storing. These are loose crystals of sulphur which can be removed by a bath in a solution of soda, as it may be deemed necessary.

When articles have been vulcanised by means of sulphide of antimony the excess sulphur, which shows on the surface, can be removed by lixiviation with caustic soda, potash, etc., and this method gives the goods the well-known pretty red colour. Vulcanised grey rubber goods of the best quality are often also lixiviated, but these goods must be made of pure rubber mixed with sulphur, as caoutchouc threads, for instance, become nearly black by the process.

Besides these methods of vulcanisation principally in use, a number of others are known, but they are all more or less variations of those which have been here described. Individual manufacturers may have special methods for vulcanising special goods, or they may employ one special manipulation, the results of practical experience, but these are regarded as valuable manufacturing secrets.

The nature of vulcanisation itself is not yet known to modern science. The manufacturers use it without understanding the complete reaction, just as electricity is used without knowing to the full the force which is handled; the phrase about "the vibration of atoms" covers a defect in our knowledge, and the same purpose is served when the vulcanisation is defined as a chemical compound of caoutchouc and sulphur. Besides this, the "chemical compound" is only a probability to some and a possibility to others, whereas others have grave doubts on the point, and some even go so far as to deny it altogether.

As long as a better explanation has not been found this may serve as the right one; those who like to follow up the matter are recommended to study carefully the meritorious and ingenious researches of Payen, Heinzerling, Unger, Donath, Otto Weber, and others. The reply which the last named gives to the question is contained in his treatise on Vulcanisation,

"Grundzüge einer Theorie der Kautschuk Vulcanisation" (Dresden, 1902), from which the following is abstracted. According to the view expressed the basis of caoutchouc vulcanisation is a pectinisation caused by chemical action, and the vulcanisation process itself consists in the formation of additional products of sulphur and polyprene. The highest limit of the additions can be expressed or represented by a body $C_{100}H_{160}S_{20}$, and the lowest limit is very likely $C_{100}H_{160}S$. The series is physically remarkable, and characterised by the lessening of elasticity and the increase of inflexibility from the lower to the higher limit. The degree of vulcanisation reached depends on the temperature and duration of the vulcanisation and also on the quantity of sulphur which has been used.

The fact remains that vulcanisation is the most critical and difficult process in the whole manufacture of rubber goods. The right temperature and time in each case, how long different pieces shall remain in the bath of chloride of sulphur and bisulphide of carbon or in the molten sulphur, in the boiler or press, and in what proportion the added quantity of sulphur must be, are all questions which the individual manufacturer has to decide and in which he must be guided by experience and common-sense. If the material to be vulcanised has been exposed to a too high temperature, over-vulcanisation or burning has taken place; the caoutchouc will have lost in elasticity and will soon become brittle, especially on the surface. If the temperature has been too low, an insufficient vulcanisation has taken place, with the result that the caoutchouc can be drawn and pressed, but it does not resume its old form as soon as the pressure has been removed. Burning or insufficient vulcanisation are two circumstances which are to be the more deprecated as the effects are often not noticed and their influence only becomes known when the articles are in use.

The time in which a perfect vulcanisation takes place depends on the quality and the origin of the caoutchouc, also on the dimensions of the articles to be vulcanised. Para caoutchouc vulcanises slower than Indian and other soft and more sticky qualities. Articles with small transverse sections are often vulcanised in an hour, whereas those with thicker walls or of larger size require two or three hours.

Walled-in vulcanisation chambers are out of date, and are principally used for the production of lacquered rubber shoes and a certain kind of waterproof cloth. The articles to be vul-

canised are spread out in their chambers at a certain distance from the floor and the walls, either in a vertical or horizontal direction. The vulcanisation here takes place through the heating of the enclosed air. It is of interest to note that this method has only the desired effect, or gives a perfect vulcanisation, when a certain quantity of litharge has been mixed with

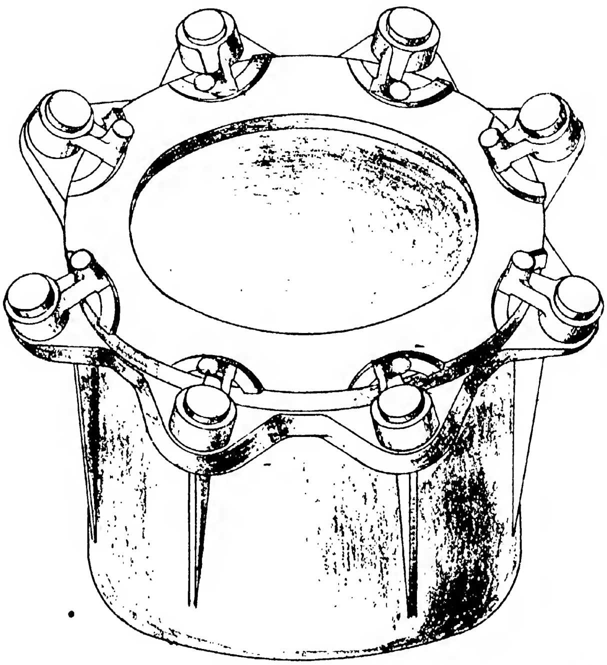


FIG. 12.—Clouth's patented cover-fastening by means of wedge faces

the other materials. The use of iron boilers with double walls, between which steam is introduced to heat the outer case, rests on the same principles. Vulcanising boilers and presses with a direct supply of steam are now in nearly universal use.

These boilers are riveted sheets of iron, like steam boilers. Their dimensions are according to the size and construction of the goods, the vulcanisation of which they have to accomplish. The diameter varies between 3 and 20 feet, and in length they measure from 7 to 10 and 100 feet and more. The long boilers are used for vulcanising hose, which has, as a rule, to be vulcanised on the cover metal on which it is made, and these

long-stretched layers require much space. The average length of hose is 60 feet in England, in France 50 feet, and in Germany about 95 to 110 feet; these measurements give the basis

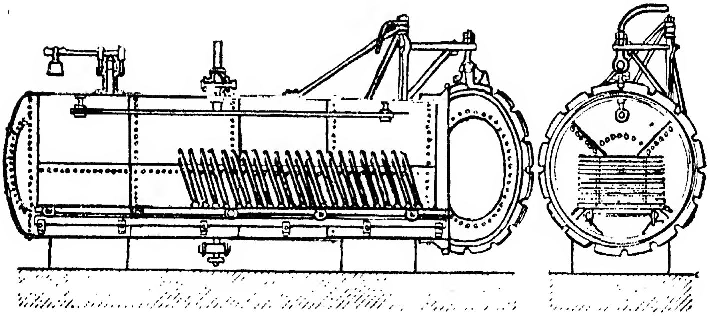


FIG. 13.

for the required length of the boiler. The open end of the boiler has a shouldered rim, on which a system of movable screws has been fixed, which fit in the notches of a similar shoulder on the

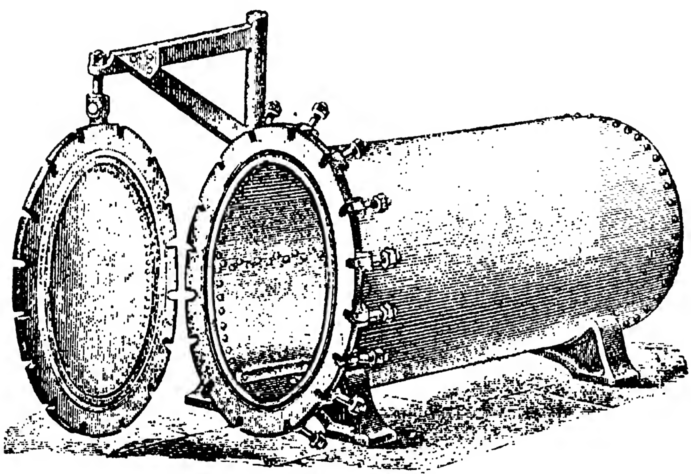


FIG. 14.

close-fitting cover; the screws can be tightened by means of nuts, and the place between cover and boiler is carefully packed.

In the works of the author, fastenings have latterly been constituted for which a patent has been granted (Fig. 12). The fastening is by means of wedge faces, which are now often

used instead of screw fastenings. The wedge faces are placed spherically round the upper end of the cover and are cast with it in one piece. On the outer flange of the vulcaniser and corresponding with the numbered wedge faces, are bolts, placed in the rim, round which revolving sliding catch-bolts are fitted. These catch-bolts, by a simple turn towards the centre of the boiler, press on the wedge faces of the cover, and a slight tapping with a copper hammer drives them over the wedge faces. The cover is thus firmly pressed against a rubber ring, and a perfect joint between it and the boiler is effected. The fitting of the set or folding-screws of the older methods meant much loss of time. The wedge-face fastening results in an equally safe means of closing the cover on the vulcaniser.

To permit of easy handling the cover generally hangs, according to the old and the new methods respectively, on a set of pulleys or a small crane. In the interior of the horizontally placed boiler a pair of steel rails is usually placed, serving for the easier moving of little trolleys on which the articles to be vulcanised are transported to and from the boiler. Several other arrangements for the transporting and storing of the articles for vulcanisation have been introduced in the modern vulcanisers, of which the special mention of the drum will be made later on.

A pipe, which can be opened and closed by a cock on the outside of the boiler, serves for the supply of steam, and another pipe has to carry off the steam and the condensed water after the process has been finished; the boilers have also provision for carrying off condensed water as soon as it forms. A manometer serves for regulating the pressure and the temperature, and a safety-valve is absolutely indispensable. The illustrations (Figs. 13 and 14) of a horizontal boiler, in transverse section and in perspective view, explain themselves. The vertical walled-in vulcanisers are of a similar construction but of smaller dimensions, being made as small as a little saucepan. These very small boilers are mostly used for experiments and for the production of patterns.

The vulcanising presses consist generally of two hollow plates (cases), which are heated to a certain temperature by means of steam; they are opened and closed by means of worm screws or levers, and for the latter purpose hydraulic power is also used.

The vulcanising press in its simplest form is not unlike the ordinary letter copying press. The lower plate rests on a table

or stand; the upper plate is carried by pillars and can be moved up and down by means of a spindle, which goes through a yoke connecting the two guide pillars, and has a long worm screw. The goods to be vulcanised are brought in closed moulds to the press, and the latter is firmly pressed down. A manometer regulates the pressure and keeps it uniform between 36 and 58 lb. The shape of these presses is either quadrangular or round; their size varies between 2 and 60 feet diameter or side line measure. Small presses can be worked by hand; for the larger, power is needed.

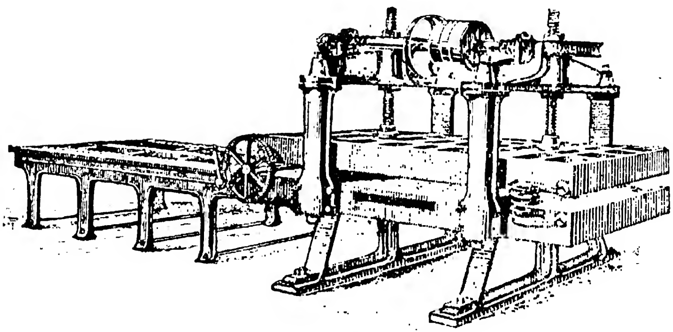


FIG. 15.

Larger presses are from 10 to 14 feet long and 3½ to 5 feet wide: these dimensions require two or three sets of worm-screws. To permit a uniform lifting and dropping of the upper plate, the worm-screws are connected and work with equal motion. Each screw has for this purpose on its upper part a toothed wheel, the teeth of which grip in the thread of an endless screw which has been fitted on a shaft placed over the press. This shaft is driven by a pulley or a worm gear, and then lifts or drops the upper plate, and controls the opening and closing of the press, just as it is desired. Fig. 15 shows the illustration of a press with two worm-screws. As can be seen from the drawing, a table has been arranged in front of the press, from which place the goods to be vulcanised are placed in the press. A second table to receive them after they have been finished can be put behind the press.

Lever presses are in little favour, although they are not impracticable, and can easily be handled.

Hydraulic presses for vulcanisation are only to be found in the larger rubber works, and even there they are mainly in use

for the production of heavy driving belts, etc. They consist in most cases substantially of two or more cast-iron plates which can be heated by steam; the plates are up to 33 feet long and 5 feet wide. The upper plate is carried by a double row of pillars, and there are up to fifteen pillars in each row, each one of which is about 3½ inches in diameter. The lower plates are movable by means of pistons, 11 inches in diameter, which are under hydraulic pressure of at least 150 atmospheres (say 920 lbs.). Articles which have been enlarged in these presses are to be placed under a total pressure of more than ten thousand tons.

On both ends of the press is generally also a stretching apparatus to stretch the belts and straps to prevent an extension in length when they are in practical employ.

To obtain the necessary pressure for the presses two twin steam pumps are required. The larger one of these pumps serves to bring the lowered upper plate quickly in contact with the fixed plates, whereas the smaller pump creates through an accumulator the necessary pressure. The lowering of the press plates follows the opening of a valve, which permits the water in the pistons to escape, when the plate sinks slowly.

Presses generally serve mostly for the vulcanisation of flat goods of larger dimensions, for press plates, plates with metal insertions, mats and stair carpets, and especially driving-belts and other articles, and this is quite clear and in accordance with their construction.

Owing to the high temperature to which the sulphured caoutchouc has to be exposed during the vulcanisation, the caoutchouc must first soften, and may consequently lose the given shape before the vulcanisation has been effected, for which reason a great many are placed in iron forms and moulds, and these find their way to the boiler and presses. This is specially the case with pump valves, buffers, thick rings, strips, cover-belts, driving-belts, billiard cushions, mats, bellows, and a large number of other articles. As has already been shown, tubing and hose are as a rule left on their puncheons during the vulcanisation, and these metal tubes are firmly covered with linen strips on the outside, which are taken off afterwards. These strips cause the texture-like impression so often to be noticed on rubber tubes and also on sheets, and these marks are often taken for a texture cover by the unsuspicious layman who does not take the trouble to investigate the matter. To produce flat surfaces, paper is sometimes used instead of the linen

strips. Thin sheets and bottle rings and frames stamped or cut out of plates are wound on so-called drums, and textile insertions are alternately placed before they are brought to the boiler. Pressed tubes, hose, and cords are laid in open or closed receptacles with a plentiful supply of talc, when the vulcanisation will be fairly equally divided between the numerous pieces.

Gummed textures are nowadays also vulcanised in boilers, whereas it was formerly the rule to treat them only with a compound of bisulphide of carbon and chloride of sulphur. The latter method is still employed for fine woollen or silken material.

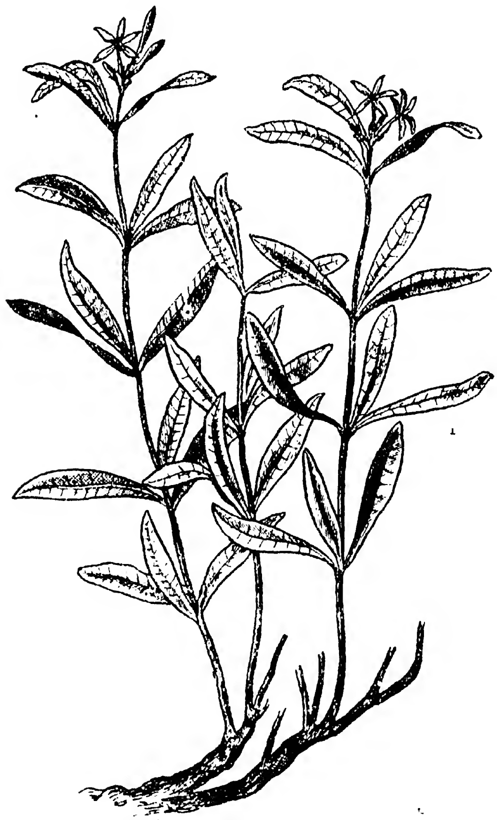


FIG. 15a.—Carpodinus lanceolata (see page 38).

VIII.—Chemical and Physical Properties of the Vulcanised Soft Rubber.

It is impossible to speak of "chemically pure" vulcanised caoutchouc in the way that the term is applied to pure acids and oxides. Raw caoutchouc contains many divergent elements, which by mixing, and in the manufacturing process, are changed, and even the most heterogeneous substances can be varied by the influence of the vulcanisation process. Every sort and each individual piece of caoutchouc is from a chemical point of view an original substance, varying from all other materials. To give a chemical formula for these combinations and compounds is for this reason quite impossible, and science has recognised the futility of fixing a standard. The analysis of a single piece offers very great difficulties, especially as long as the vulcanisation and the chemical changes which it causes have not yet been fully investigated and fixed.

Quantitative analysis only tells us the quantity of pure rubber present, and it discloses neither the nature nor the origin of the raw material which has primarily been employed. As these are mainly responsible for the quality of the material, it is clear that a clearer chemical analysis must be of the greatest value in this direction, but present knowledge is very limited.

Even the specific weight does not give a sufficient clue, as so many assume, and the belief that this is a qualitative measure of the excellence of the vulcanised caoutchouc cannot be entertained; it is not always that with the lighter specific weight which is the better quality. It is a nearly universal assumption that vulcanised rubber with a specific weight of 1.0 or less, which floats on water, is a superior quality. Nothing is more erroneous. Raw caoutchouc of the best or most inferior quality, the most expensive fine Para and the cheapest West African, has an average specific weight of 0.925. These naturally float on water, and if the floating is a sign of quality these sorts must be of equal value.

Not even the quantity of foreign substances can be fixed by specific weight; some of these are of lighter specific

weight than raw caoutchouc, and others, as for instance magnesium, expand during the vulcanisation and at the same time reduce their specific weight. The only standards for the absolute quality of vulcanised rubber are the nature and origin of the raw caoutchouc employed. The relative quality, *i.e.*, with regard to use for particular purposes, depends on the right selection and the proper proportion of the mixture. Sorts with a high specific weight may be superior in quality to light goods, and thus may be more useful for their purpose. Manufactured goods of a specific weight of less than 1.0 are comparatively rare, and unless they are made light by artificial means they are never under 0.96 and 0.95. The specific weight rises on the other hand to about 2.0, and even higher, and some of these qualities have proved to be the most suitable in use. The specific weight is therefore no criterion to judge by whether the product is the best for the purpose, especially as the mixing of certain heavy substances frequently causes the articles to become more suitable for their particular purposes.

Vulcanised caoutchouc has a peculiar, very characteristic smell, which is not easy to describe, but it may be taken as sufficiently well known, although it can be found in numerous variations. The smell is on the one hand influenced by the nature of the raw caoutchouc, and on the other hand by the additions of sulphur, bisulphide of carbon, chloride of sulphur, and also benzin and other solvents. The smell develops less in a low temperature than in a higher, and it becomes particularly strong when about 100° F. have been reached. The endeavour has been made to remove the smell from vulcanised rubber, but nobody has yet obtained a lasting result. The best deodorising agent hitherto found is finely powdered bone charcoal, but the result is not lasting, and as soon as the charcoal is removed the smell breaks out afresh. Treatment with ether oils proved equally a failure, as the oils soon volatilised.

The colour of vulcanised rubber, consisting only of caoutchouc and sulphur, is light grey. Pure Para and other related qualities show sometimes, but not always, the brown and characteristic Para spots. Mineral and other additions, not to speak of colouring material, make the vulcanised caoutchouc white, yellowish, or more or less dark grey and black.

The porosity of the vulcanised rubber is much less than that of natural caoutchouc. Equal quantities were put for testing purposes in water, and the raw caoutchouc absorbed 0.20, rubber

mixed with sulphur absorbed 0.064, and vulcanised rubber 0.042 parts of water. Compared with this result, it is surprising to find that air and gases go under the same pressure, through equally deep walls of raw caoutchouc, mixed, and vulcanised rubber, and that the material absorbs equal quantities in the same period of time.

Tests have shown that equal quantities have diffused through a thin caoutchouc sheet as follows:—

Nitrogen	1,000	times
Carbon monoxide . .	1,100	,,
Air	1,149	,,
Marsh gas . . .	2,148	,,
Oxygen	2,256	,,
Hydrogen	5,500	,,
Carbonic acid . . .	13,585	,,

The power of self-adhesion, one of the most characteristic properties of raw caoutchouc, disappears in the vulcanised rubber, and this peculiarity is lost to such an extent that it becomes difficult to connect firmly two pieces of vulcanised rubber even when strong solutions and gluing materials are employed. Of a spontaneous and structive connection, as was possible before the vulcanisation, no traces are left.

The foremost and most characteristic property of vulcanised rubber is its elasticity, *i.e.*, the power to follow a pressure or a pull and as soon as this ceases spontaneously to return to its old form. It possesses this property to a much higher degree than unvulcanised raw caoutchouc. M. A. Steward, Emilio Villari, W. Thomson, P. S. Tait and others have made interesting tests regarding the elasticity, and without much difference they came to the remarkable conclusion that all deformations which vulcanised rubber may be subjected to do not decrease its bulk. By pressure from the top it expands at the sides in equal proportions as the height of the article decreases, and *vice versâ*. A round cord strongly pulled loses in its transverse diameter in equal proportions as the length expands. The contents of a hollow cylinder filled to the top with vulcanised rubber and under very strong, even hydraulic pressure by means of a stamping shaft, could not be seriously pressed down, and the volume of material could not be diminished. Vulcanised rubber acts towards pressure in a like way as water. The French *Chemin de Fer du Nord* has made such tests, and it was found

that the total of the recorded reduction amounted to not more than 0.00009295 of the total, and the pressure amounted to one kilo per square centimètre.

Vulcanised rubber is like the raw product, and even in a still higher degree a very bad conductor of heat, and an excellent insulator of electricity.

Unlike natural raw caoutchouc, which loses its softness and elasticity in a temperature under freezing-point, vulcanised rubber retains all its distinctive properties, however deep the mercury may sink. It becomes inelastic when the thermometer is extraordinarily low, but even then pulling and pressing soon gives it back its usual elasticity. If covered with cold water it is not directly influenced, and no change takes place; on the contrary, cold water preserves the rubber, and even stops the decomposition which nature has otherwise decreed for it. As long as the pieces of rubber are covered by boiling water, it has no influence, but if the pieces are only partly covered, and after these have been taken out, light and atmospheric air have a decomposing effect; the pieces soon become hard and brittle on the surface, and the decay slowly extends to the interior. Blazing sun-rays are the worst enemy of vulcanised rubber, especially if the surface of the goods has been wet or moist. Simple dry heat, even with temperatures up to 120° F. and a little over, has no deteriorating influence. Under a temperature of 360° to 400° F. the rubber begins to melt, it loses its elasticity altogether and becomes sticky. If the temperature is still increased, the material soon becomes a carbonised substance. Under the direct influence of steam at a temperature of over three temperatures it burns on account of over vulcanisation, which ends at last in a perfect carbonisation.

The destructive influence of light and atmospheric air on vulcanised rubber when in a wet or moist condition has already been mentioned. The same deteriorating causes are at work, even if not to the same degree, on dry rubber, and are caused by light, especially if working in conjunction with heat, as, for instance, direct sun-rays. The interesting observation has been made that a fine-cut sheet mixed with sulphur and exposed to the influence of light was partly vulcanised. This experiment shows the destructive influence light must have on rubber which has already been vulcanised. The influence of atmospheric air is less grave than that of light, it makes itself known by a slow process of oxidation, which first attacks the surface of

the rubber, and slowly goes deeper and deeper, accompanied by molecular changes. Everything has been tried to stop the influence of oxidation. Additions of coal tar have sometimes proved successful, but these results were not always to be obtained. The causes of the oxidation are probably not yet known, possibly it is the result of continued vulcanisation, and the effect is influenced by the superfluous quantities of sulphur. The solvents, bisulphide of carbon, benzin, petroleum ether, turpentine and others, which dissolve raw unvulcanised caoutchouc perfectly, have less effect on vulcanised rubber. They dissolve it only to a small extent, but they swell it up enormously, often to ten times the volume of its original bulk. Fatty oils have a similar effect, and also alcohol. If vulcanised rubber is subjected for longer periods to the influence, it turns to a plastic mass, which easily oxidises in the open air.

The vulcanised rubber is not easily influenced, and resists the effect of alkalies and acids. Salt, soda, potash have no effect, just as little is it influenced by tartaric, hydrochloric, and acetic acids, more so by sulphuric and intro-muriatic acids, but even these are offered much resistance, which depends on the quality of the material; pure Para with few additions can long withstand all these influences. This qualitative property has made caoutchouc long an indispensable material for chemical factories, which use it for lining and connecting of tanks and other vessels.

To produce rubber goods rationally it is necessary to know the uses the different articles are intended for, and what purposes they will have to serve. It is necessary to have this knowledge as a basis for calculating the effects these uses would have on the materials employed, and practical experience and the principles of science are necessary to form a proper judgment. Only with this fuller knowledge will it be possible to make a proper choice of the rubber qualities to be used, several of which can probably be compounded; it is furthermore of influence by fixing the nature and quantities of the mixing materials, the degree of vulcanisation, and the finishing of the goods. The required softness, toughness, hardness and elasticity cannot be obtained without this study, and these influence to a high degree the resistance towards heat and cold, gas, steam, oil, acids, and electricity. The use of the inferior raw caoutchouc is reprehensible where it is not suited to the requirements of the quality and the application of the goods,

it is equally objectionable to mix caoutchouc with unsuitable foreign substances which have not been chosen with the proper end in view, only because the price of the material is cheaper. It is regrettable that the purchase of goods and, through this, their production, is mostly only guided by a desire to obtain them as cheaply as possible, regardless of the old axiom that a low price necessitates an inferior quality, especially as the look of the goods does not in this case represent or indicate their intrinsic value. The principle of asking for tenders for contracts is theoretically quite sound, but in practice it has brought about the production of the worst kinds of goods. It has been proved that the American pays 100 per cent. more for rubber goods for his own use than the German; the Russian pays 50 to 60, and the Englishman, on the average, 30 to 40 per cent. more, and it is sure that all these fare much better in the course of time than the German. The consumer of rubber goods can only be recommended to purchase his goods from trusted and recognised sources, from manufacturers who understand their business; they know the materials and their proper application, and in case of doubt it is well to leave the choice in their hands, even at the risk of having to pay a seemingly high price. The result will benefit the purchaser and bring credit to the manufacturer, whereas a momentary saving ends always in disappointment and loss of money and time.

The best storing-room for vulcanised rubber is a dark, cool, well-ventilated chamber, basement or cellar, where not too large quantities can be piled up. Still better, it is conserved under cold water in lightless chambers, where the deteriorating influence of the atmospheric air is hindered. But the very best way of keeping rubber goods is, ordinary wear and tear being taken into consideration, every-day use. Pump valves, which have been two or three years under water, have been found, when taken out, in excellent condition, whereas reserve valves which had been sent at the same time, and were kept in a storeroom, had much deteriorated. Made of the same material and at the same time, they lost much in elasticity, and sometimes they were proved to be absolutely useless.

IX.—Hard Rubber (Ebonite).

THE first hard rubber was manufactured by the American Goodyear, and he must be considered as the inventor. Others have since taken a lively interest in the product, and have followed up the ways of making the material. Improved manufacturing methods were invented, and owing to the great value the rubber industry at once detected in the product, means were found to improve the quality.

On the whole, the production of hard rubber rests on the same principles as the manufacture of vulcanised rubber. The raw caoutchouc is washed, dried, kneaded, and mixed with other caoutchouc qualities and suitable filling materials. The addition of sulphur amounts sometimes to about 60 per cent. It must not be forgotten that the larger or smaller quantities of sulphur added to the caoutchouc influences the hardness of the products; the use of larger or smaller quantities of sulphur results in greater or diminished hardness. But the sulphur causes brittleness, and when more than 50 per cent. of sulphur has been mixed with caoutchouc, the product breaks like glass if only slightly bent. Besides sulphur, which is sometimes supplanted by a sulphide, the material entering the mixing rolling-mill receives additions of chalk, zinc-white, magnesium, resins, antimony of sulphur, sulphuret of mercury, and other substances in proportion to the required elasticity, hardness, or flexibility, and also colour, and these are obtained by the proper mixing of the material. These preparatory operations must be much more carefully conducted than the production of soft rubber. Should air bubbles be caused by enclosed small quantities of water, which evaporates during the manufacturing process owing to the high temperature, the material becomes porous, and under some circumstances it is quite useless.

The production of individual articles out of hard rubber is nearly the same as described for soft rubber goods; the prepared raw material is drawn into sheets of different dimensions, and the articles are formed out of these as desired. Insertions or fillings of tissue made of vegetable substances and metal are seldom employed, there is only occasionally need for them; the

nature of the material excludes their use, and their presence could only cause annoyance during the further procedure. The vulcanisation generally takes place in metal frames or moulds. Tubes are wrapped in cloth, and these are vulcanised on their puncheons, as has been described in the soft rubber production. The vulcanising boilers and presses are the same as for soft materials, but the required heat for hard rubber-goods production is much higher than before described, and reaches occasionally to 330° F. For very good reason the process is generally started with a lower temperature, about 250°, which is slowly increased to about 300°, 320°, and even 330°, as already stated. The time needed for the vulcanisation or manufacture of the hard rubber depends largely on the composition of the material and the size of the different articles. It may be 6 to 8, and 8 to 10, and even 10 to 12 hours.

The physical and chemical properties of hard rubber are different from those of vulcanised raw caoutchouc, and give hardly a reminder of the original material. Hard rubber is black, quite inodorous, like horn and hard wood, and not unlike ivory. It is absolutely impervious to electricity, but under strong friction, or when rubbed, it becomes strongly electric. Cold water, light, and atmospheric air effect no change in it, and it does not oxidise. Put into boiling water, it becomes smooth and can be bent. Solvents which dissolve the natural raw caoutchouc, and partly dissolve vulcanised soft rubber, have no influence at all on it, and the material offers the strongest resistance to all kinds of acids. If it is exposed for a longer period to a dry temperature of about 400° F., it does not become first sticky and then melt, as happens under the circumstances to raw caoutchouc and vulcanised rubber; it carbonises at once, and goes through no intermediate stage.

The material can be worked on a lathe, with a saw, a plane, a cutting-machine, or a rasp, and it is easy to polish. This makes it not only useful for technical purposes, but has brought it into the household, and in the fancy-goods trade hard rubber goods are much appreciated and largely produced. It is now preferred to horn in the manufacture of combs, as it has not a fibre-like structure, and large quantities are used for this purpose. A large number of other articles are manufactured from it, such as knife handles, buttons, rulers, drawing rules, instruments for draughtsmen, bottle and glass saucers, match-boxes, penholders, bracelets, chains and similar jewellery,

ornaments and trinkets, besides imitation jet; and sometimes, when it receives an exceptionally fine polish, it is used to imitate onyx. Many of these articles come out of the moulds with a dull, dead colour, and the pieces need a good polishing, to which the material is very amenable. The polishing is either done on the lathe or by means of polishing discs of cloth or felt, and sometimes other means have to be employed. The polishing increases the cost of production immensely, and many inventors have tried to find other means for achieving the same result. Many of the improvements, if they do not make the polishing superfluous, have at least brought the methods so far as to render the work much easier. The use of forms or moulds of glass, or lining the iron moulds with a layer of tinfoil, has proved to be very successful.

Articles made of hard rubber for technical use require as a rule no polishing, but plates and sticks for electrical purposes, not to mention a few other articles, are an exception to the rule. In most cases it is only necessary to remove the seams of the moulds and possibly a dull polish is given. Hard rubber is also used for photographers' developing tanks, powder spoons, scoops and scales for chemists and laboratories, tubes and pipes, cocks, and whole hand and steam pumps, as lining and packing of centrifugal kettles and other vessels for acids, and also as coverings for certain steamship machinery parts, to make them impervious to sea water, and many other purposes. For electrical purposes hard rubber is quite indispensable; it is used for discs of electrical machines, insulation caps, and insulation tubes for electrical conduction, and especially for cases for accumulators.

It is necessary for certain purposes to manufacture a hard rubber which has a greater elasticity than the ordinary material, and often a greater flexibility is also required. The product which has been brought out to meet these requirements is called a half (semi) hard rubber, and the designation gives the clue to the production of the article. In its composition there is more sulphur than in soft rubber, but not so much as in hard rubber, and the compounded mass is exposed to a higher temperature and for a longer period than is suitable for soft rubber goods, but again it must not be heated too long to risk it coming out as firm as hard rubber. The proportion of the needed modifications depend on the required hardness, elasticity, and flexibility, and also how the material has been mixed.

Many articles of the rubber-goods industry need a combination of hard and soft rubber, between soft and semi-hard, semi-hard and hard, or even between the three kinds. These combinations are required for the lining of acid vats, the production of cylinder covers, especially for those of larger dimensions, and also for paper production in leather factories, and for finishing and dressing of cloth, besides for many other purposes. How these combinations have to be made is a question which can only be solved correctly and adequately by the most careful study of the requirements, the closest supervision of the workmen, and the most careful choice of the quality of raw caoutchouc and the additional substances; finally, many years of experience in vulcanising are needed, as this process is the most difficult problem in the manufacture of rubber goods.

X.—Recovered Rubber and Substitutes for Indiarubber.

THE large consumption of vulcanised rubber leads to an enormous accumulation of old rubber, and to this must be added the waste when goods are cut or stamped out of sheets and plates, and also the pieces which for one or other reason, as for instance, cutting of wrong dimensions or faulty production, cannot be usefully employed. The high price for raw material has for this reason placed before the manufacturer and chemist the problem how this old material can be made useful in further employment in the rubber-goods industry. Soon after Goodyear's momentous invention of vulcanisation, about the middle of last century, a few Americans made the first experiment in this direction, and English, French, and German chemists soon followed enthusiastically in the same field. The ideal solution would be doubtless to extract by a chemical process from the used and vulcanised rubber goods and virgin caoutchouc. All endeavours and trials in this direction have proved futile. It was not found possible to undo vulcanisation altogether, and it is doubtful if the endeavour will succeed in future, because the sulphur forms a chemical compound with the rubber and cannot be extracted without destroying the caoutchouc. The method of devulcanisation must therefore be concentrated on the point of extracting from vulcanised goods the superfluous sulphur which has not entered into a chemical combination with the caoutchouc. Ways and means have been found in this direction to use the old material, if not independently, at least as an addition to raw caoutchouc. To obtain cheaper qualities which serve many purposes the reclaimed material is of excellent service, and its rational use must be permitted for economical reasons. Under certain circumstances, moreover, it allows a desired effect to be produced which could not otherwise be so easily obtained. The material should always be employed with discretion, especially if the manufacturer uses regenerated rubber which is not reclaimed in his own factory. In this case he cannot tell what kind of raw rubber has been

employed, and how the material has been used during its manufacture. It is possible even that the goods were already partly of regenerated rubber, and it would be impossible to tell what proportion of this had been used.

It is not the intention to give here a historical survey of the development of regenerated rubber and its devulcanisation, but it must be pointed out as already mentioned, that in the middle of last century Mr. Hiram L. Hill, of the Beverly Rubber-works in Massachusetts, patented the first reclaiming process, and the patent has been followed by numerous other ones.

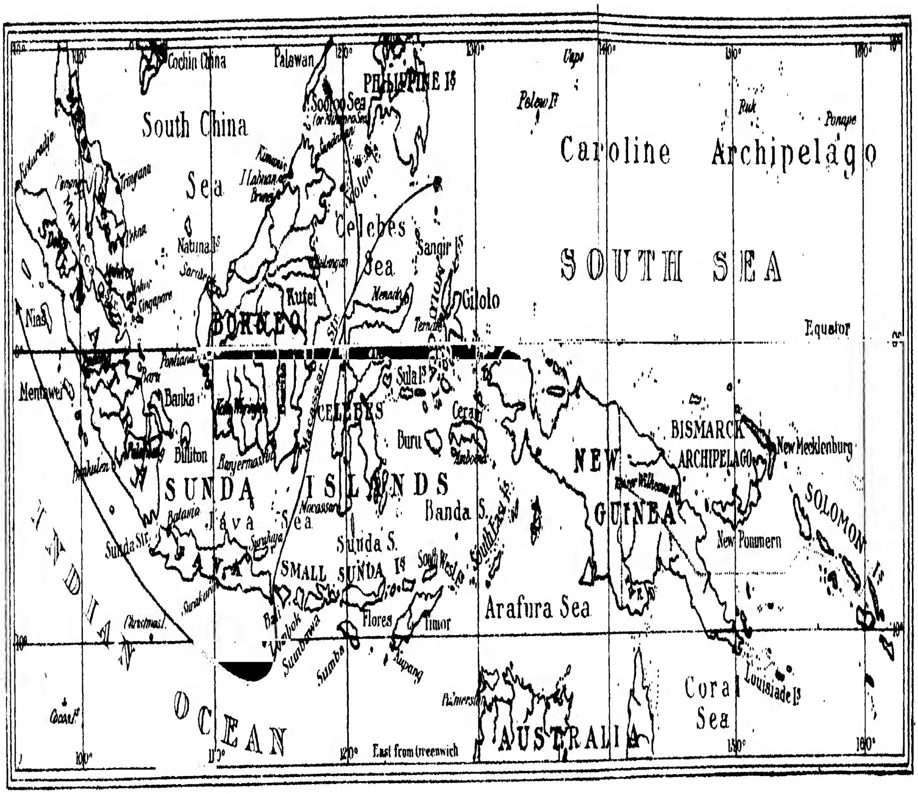
Two methods of reclaiming rubber out of vulcanised goods for re-employment are recognised—one mechanical and the other chemical.

In the mechanical process the rubber is ground to fine powder, and by means of magnetic dividers all iron is extracted, and lighter ingredients, such as fibrous and vegetable components from lining materials—cotton, hemp, jute, etc.—are blown out with a special apparatus. Sometimes the powder is exposed to a high temperature to extract the uncompounded sulphur, but in most cases the latter procedure is not adopted, and the material goes direct to the mixing-mills. Of much greater interest is chemical reclaiming. This is based on the removal of the sulphur by means of an alkali which is afterwards washed out. An addition of oil, paraffin, or naphtha, kneading and warming it up to 250° to 300° F., makes the mass equally cohesive and plastic, and it can be rolled out on the calender like unvulcanised rubber. Sometimes virgin caoutchouc scraps are added at this stage. The main point is in the regaining of the plastic properties; the more perfect the success is in this direction, the better is the reclaimed rubber for fresh vulcanisation. The qualitative excellence depends certainly on the original quality of the caoutchouc, and good original material is sure to supply a relatively good reclaimed rubber. It must also be mentioned that reclaimed rubber from old rubber shoes is particularly excellent for certain purposes. Russia, which has the largest sale of rubber shoes in Europe, supplies for this reason large quantities of old material to English, French, and German manufacturers.

The high price of raw caoutchouc, which led to the endeavour to reclaim old rubber for re-use, also led to the attempt to provide an artificial material as a substitute for caoutchouc, whose properties would be as much as possible identical with those of

the genuine article. The one question is as old as the other, and both have been long before the chemists. France has contributed much to the solution of the problem, and from this country came the first substitute for raw caoutchouc put on the market. From its French origin the material has been universally named "factice," and all other surrogates made with vegetable oils, linseed oil, rape-seed oil, cotton-seed oil, etc., are called by the same name. To produce factice the oil undergoes an oxidation process, afterwards it is heated, mixed with sulphur and cooled, when it becomes a brittle powder, which is added to the caoutchouc mixture immediately before use.

The use of factice does not, on the whole, contribute to an improvement in the quality of vulcanised caoutchouc, but in many mixtures and for several kinds of raw caoutchouc it preserves the substances, and in these cases it can be employed with advantage. To enter into greater detail on this subject is outside the sphere of this book, which, as has already been stated, is not intended to be a guide to manufacturers. The material owes its original introduction into the production of rubber-goods to the senseless desire for cheap goods and the outcry for low prices. Conscientious manufacturers for a long time declined to adopt the substitute for ordinary use, and in many cases they are of the same opinion to-day, although they have been forced to make use of the product for several purposes, only because competition has forced them to do so. This is very deplorable, but the circumstances cannot be altered until the public has learned not to judge only according to the quoted prices but also to consider the quality. To recognise a good and bad rubber quality in finished goods is not an easy task, and much should be left dependent on the reliability and the trustworthiness of the producer, whose interest it is to supply the purchaser with the best goods.



GEOGRAPHICAL DISTRIBUTION OF GUTTA-PERCHA SUPPLYING PLANTS.

GUTTA-PERCHA.

I.—Introduction—Historical.

CAOUTCHOUC in the manufactured state is often called gutta-percha, and the public seldom make a distinction. They treat the terms as identical, mistaking one substance for the other. But even technical men have fallen into this trap when placing orders, causing great confusion and many serious misunderstandings, as all manufacturers in our trade are only too well aware. This has been caused by the great expectations raised by gutta-percha when it first became known, which have not been fulfilled, and also because the two materials have some similarities in origin, collection, and manufacture. Gutta-percha, however, has not the elasticity of rubber and cannot withstand changing temperatures to the same extent. Gutta-percha has, on the other hand, some advantages, of which its greater density is the most prominent.

John Tradescant, the English naturalist and traveller, at one time head-gardener to Charles I., first brought gutta-percha to Europe in 1656, and called it "Mazer wood." The sample caused many curious inquiries, and it is reported that it is still to be seen in the Tradescant Museum in South Lambeth, London. Nobody took a serious interest in the sample, and as for the use of the material, nobody gave it a thought. Even at the beginning of the nineteenth century no further knowledge of the subject had been acquired, and as the scientists and manufacturers carefully inquired into the use of caoutchouc, gutta-percha was spoken of as an inferior material, a cheap, inelastic, and little flexible substance which could not compete with a Brazilian or East Indian caoutchouc. The drawbacks alone of the product were recognised, of its advantages no one had the faintest idea.

In 1832 the English medical resident at Singapore, William Montgomery, heard of a curious kind of caoutchouc which the natives used for making the handles of tools, and under great difficulties he succeeded in learning a little more about the sub-

stance. He found that the material became soft in boiling water, and could be moulded, and that it was much tougher and harder after this process than before. This information induced Montgomery to take the trouble to investigate the matter. He bought some samples and soon recognised their superiority over caoutchouc for making surgical instruments, especially as the latter, made of caoutchouc, soon become sticky in the moist, hot climate of the inter-tropical zone. In 1843 he reported his researches to the Medical Board at Calcutta. The contents of the letter announcing this are important; it has been published in the *Journal of the Agricultural and Horticultural Society of India* (vol. ii., 1843), and possesses great interest from a historical point of view, especially as it is the first published document referring to gutta-percha. A full reproduction in these pages is for this reason permissible. He writes :—

"SINGAPORE, 1st *March*, 1843.

SIR,—I have the honour to request that you will lay before the Medical Board the following short account and accompanying specimens of a substance called by the Malays gutta-tuban or gutta-percha.

"It is the production of a large forest tree indigenous to Singapore and the neighbouring countries, and is procured by cutting through the bark, when a milky juice exudes. I am informed that the produce from one cut is not very abundant, and ceases to flow after a time, but that the tree continues to give it forth after being again cut into for the purpose.

"Soon after the juice is collected, great part of it coagulates into a substance which continues white if excluded from air and light. When dried in thin layers exposed to the atmosphere, it very much resembles scraps of leather. It appears, from some very imperfect experiments, to resemble caoutchouc in its chemical properties, but is much less elastic. It, however, possesses some qualities which, I think, will render it a valuable substitute for caoutchouc in the manufacture of bougies and catheters. Instruments made of the latter substance invariably get spoilt when kept for any length of time in a hot, moist climate, and I believe that this is in a great measure the consequence of its being necessary to use some of the essential oils or naphtha as solvents for the caoutchouc; but this is quite unnecessary in the manufacture of instruments

of gutta-percha, it being only necessary to plunge the piece of gutta of the proper size into water heated above 100° of Fahrenheit, when it becomes quite plastic, and may be readily moulded into any required shape and rolled quite smooth between two even surfaces; it retains the form when cold, and is more rigid and harder than indiarubber at any temperature below 110° of Fahrenheit; it possesses also the valuable property of fragments of it being perfectly united when dipped in water heated near the boiling-point.

"It, however, more readily than caoutchouc, receives marks and dents from pressure in contact with rough, hard surfaces, and such collision must be avoided. I am of opinion that bougies formed of gutta-percha will be found very serviceable in cases of deep-seated strictures, when it may be required to have the body of the instrument firm and rigid; as one of the full size may be used by merely dipping the point into hot water, and an inch or so may be moulded between the fingers and thumb to any required size and rolled smooth on the table with a paper-folder or anything of the kind, and in the course of a few minutes it will be fit for use. From its being plastic and readily united, it will also be found serviceable in the formation of catheters or canules.

"I have not been able as yet to get the flower or fruit of the tree producing this gutta. The situation from whence the specimens I have obtained were produced is the forest about six miles from the town of Singapore, at a place much infested by tigers, and to which it is necessary to proceed on foot, so it would be a venture of some risk to proceed to the spot; but I have offered a reward for specimens of the flower and fruit of the tree, and am in hopes of being able to procure some ere long.

"I am informed that the fruit is as large as a pigeon's egg, and produces a concrete edible oil, so in all probability it is not one of the figs.

"Herewith I have the honour to transmit some of the articles—three bougies, which I have attempted to make by simply rolling the gutta on a common table under the hand and afterwards with an ivory paper cutter; they are, of course, very imperfect specimens, but sufficient to show what, under skilful manipulation, may be made of it. I also send the handle of a chopper made by the Malays, for which purpose the gutta is preferred even to horn. I have the honour to be, etc.,

"W. Montgomery, *Senior Surgeon.*"

Montgomery at the same time asked his friend Dr. José D'Almeida to acquaint the Royal Society of Arts in London with the facts. He was awarded the gold medal of the Society.

To make commercial experiments D'Almeida handed small quantities of the so-called caoutchouc to English manufacturers who at once started making trial of them.

The first patent for the working of gutta-percha was granted to R. A. Brooman on March 11th, 1845, the second English patent was granted on January 12th, 1846, and the third on February 10th, 1847; the latter two were granted to Charles Hancock.

Gutta-percha was first introduced into France in 1845. Lagrenée, whom some business had brought to China in 1845, procured a quantity of gutta-percha at Singapore on his return journey and made a present of it to the French Minister for Commerce. The following year the first application for patents for gutta-percha goods was applied for by Alexandre, Cabriol and Duclos.

The gutta-percha has thus found its firm foothold in the industry. Looking back, it is remarkable that the origin of the gutta-percha from a botanical point of view had not received more attention and remained in the dark. It was Dr. Thomas Oxley, Montgomery's successor, who first gave a description of a tree which at that time supplied gutta-percha; it was the botanist, Sir William Hooker, who christened the tree *Isonandra gutta*.

To report all the details of the progress of the young industry would lead much too far; a few remarks must be sufficient to explain how gutta-percha gained its influential position. The endeavour has been made to use gutta-percha for all articles made of caoutchouc, and the patents became so numerous that it is evident that there was a craze for the new material. Corks, glue, thread, boots, chirurgical articles, garments, tubes, plates for ships' armour, even whole boats were made of it, and if a report of the Great Exhibition in London in 1851 (by Ballard) is studied, the immense enthusiasm for the material becomes clear. Of all the more or less sensible applications of gutta-percha only a few have survived, and if it had not proved indispensable for certain purposes the manufacturers would soon have dropped the material.

The characteristic properties of gutta-percha are all against the uses it was then put to. The greatest difficulty lay in the

circumstance that the material became plastic when heated, and some tried to improve it by vulcanisation, but the influence of sulphur on gutta-percha differs from its effect on caoutchouc. All expectations were destined to be short lived, and as Guilbal says in his report on the 1876 Exhibition, the results obtained were a relative failure. The recognition of its unique properties, first considered as drawbacks, came just in time. If gutta-percha had come on the market at the same time as caoutchouc it would not have been given much consideration. But the recognition was coincidental with the rise of dynamic electricity. It was soon found that gutta-percha insulates and that it remains unchanged in salt or sea water. Needless to say its use for covering and insulating telegraph cables became at once apparent. The honour of producing the first gutta-percha insulated telegraph cable belongs to the German, Werner Siemens, who, in 1847, constructed the first line along the Anhalt railroads. The Englishman, Wheatstone, who, about 1837, conceived the idea of a telegraph connection between England and the Continent, had also his eye on gutta-percha for the production of submarine cables, but his ideas were only realised by Walter Breit, who, on the 10th of January, 1849, laid the first two-miles-long submarine cable. The Society of Arts took a great scientific interest in the new material supplied to the industry. The Journal of the Society contains in its issues for the earlier part of 1852 many articles referring to gutta-percha, amongst which are some by Professor Bleekrode, Mr. Murton, Mr. James Collins, and Mr. John Jackson. On 24th February, 1858, the Society nominated a committee to make some experiments with gutta-percha and to report from time to time. It was intended to investigate the nature and cause of the coagulation, the different qualities, the methods of adulteration, and any other points of interest to the manufacturer and the consumer. The committee consisted of Prof. Edward Solly, Prof. John Lindley, Sir William Siemens, Mr. Latimer-Clark, and Mr. Edward Highton. To arrive at correct conclusions twenty-five questions were drawn up at the first meeting referring to the nature and origin of gutta-percha, its production and properties, and its cultivation. These questions together with a memorandum were sent to all persons acquainted with the subject or from whom any information might be expected. Many points until then not cleared up found thus an explanation, but many others have remained in

darkness up till now. The Committee met until January, 1860, when it had become clear that the main value of the material was in its insulation properties for electric cables, and this point once recognised was considered of such importance that a Government Commission was nominated to investigate thoroughly the insulation question for telegraph cables. In the meantime gutta-percha had also been used for producing other kinds of goods. The resistance of gutta-percha to acids led to its employment for making receptacles, funnels, and tubes, to be used in chemical factories and photographic and other laboratories. Driving-belts and ropes were made of it, and it was found particularly useful for making strongly marked forms as required for galvano-plastic work.

Although the employment of the material in comparison with its first use soon became restricted, and only found application for purposes which it was absolutely essential, the demand for the raw material increased very much, and it was evident that the sources of production would soon be exhausted. It was, therefore, only a duty for the governments of civilised nations to investigate this state of affairs, the more so as the Malays and Papuas think more of an immediate gain than of the future, and they neither tried to improve their collecting methods nor did they try to increase the annual production by improved cultivation, which at least would keep the quantity of raw material to its old figure. This important point will find further consideration later on, when a statement of what has been done not only by private undertakings but also by the English, German, and Dutch Governments, to avoid a total exhaustion of the gutta-percha sources, will be given.

It was a further epoch-making moment in the history of gutta-percha and its production when in 1888 E. Jungfleisch made the discovery that pure gutta-percha could be extracted from all parts of the gutta-percha supplying plants, especially from the leaves and the branches. Besides Jungfleisch, who gave the first intimation of the possibility, Rigole, Sérullas, and Obach, have contributed largely to the solution of this question. This point will be referred to further in other parts of this book.

II.—Natural History.

MUCH has been written about the name gutta-percha (also gutta-pertcha, gutta-tuban or taban, gentiana gum; Latin: *gummi plasticum*), and it was energetically debated whether gutta-percha or gutta-tuban or taban was correct. The word gutta (Malayan *guetah* or *gueutta*) means, according to Sérullas, the same as caoutchouc; but this writer asserts that the words pertcha or perfia cannot be translated. Sumatra is in Malayan *Perna*, meaning a world or inhabited continent, whereas pertcha means a piece or a scrap; consequently the latter word is very characteristic, as the caoutchouc looks like scraps before it is treated in hot water. The word does not belong to the vulgar Malayan language, for which reason it cannot have been first applied by the natives, but by the traders. The usage of language has, in England, France, and Germany, rightly or wrongly, fixed on the term gutta-percha, and it remains only to be considered if it is advisable to give the chemically pure material another name than the raw product. Gutta-percha is in its natural origin and composition a vegetable product much like caoutchouc. It is produced from the latex of trees and is equally a hydro-carbon, consisting of equal parts of carbon and hydrogen. But here the analogy ceases, and it is astounding how products with so many varying properties could for so long be considered as one and the same substance. Morellet has explained the heterogeneousness of both substances in several of his books which have already been mentioned. He says: "Caoutchouc is primarily an elastic body, *i.e.*, a substance which has naturally only little capability to remain in a form which the influence of mechanical power has given it; but gutta-percha can retain the form into which it has been pressed. The natural and unvulcanised caoutchouc remains soft and becomes more flexible under the influence of heat, it also remains elastic as long as the heat is not too great and takes from it its physical and chemical nature and properties. But gutta-percha becomes flexible and can be kneaded when submitted to a carefully applied temperature of 212° F. or in boiling water, and when it becomes cool it retains the form which it has thus acquired."

The two main properties can already be gathered from the Latin names of the two substances, *gummi elasticum* for caout-

chouc and *gummi plasticum* for gutta-percha. Morellet continues: "Caoutchouc loses under the simultaneous influence of air, heat, and time the before-mentioned characteristics, and becomes a sticky, tough, and more or less fluid substance, whereas gutta-percha becomes brittle and resinous under the same conditions. These changes require more or less time according to circumstances. Water and low temperature delay the changes of both products. The hitherto collected observations show the greatest dissimilarity between the two substances just in these properties."

A further important difference is shown when both materials are brought under the influence of sulphur. When caoutchouc and sulphur are compounded, a chemical combination is effected by the vulcanisation, and without much trouble an elastic material is obtained which retains its properties under changing temperatures as long as these do not go beyond 300° F. A chemical combination of gutta-percha and sulphur is altogether out of the question, even a compound of caoutchouc, gutta-percha, and sulphur, has, according to the quantity of gutta-percha it contains, a more or less negative result. The dielectric properties of both substances are not the same, another reason to differentiate sharply between *gummi elasticum* and *gummi plasticum*. As will be seen later, the differences have their origin in the botanical nature of the plants producing the material and in the consequent difference of the latex.

Before this point can be investigated it is necessary to fix the meaning of the words "gutta-percha." Scientists, travellers, and manufacturers cannot give as much information on this point as concerning the origin of caoutchouc. There is hardly a doubt that the first Para caoutchouc was the product of the Heveas, but the original supply of gutta-percha is shrouded in mystery, and it seems sometimes as if perversity would withhold or willingly frustrate all elucidation. After forty years of study and research about the doubtful point Dr. Beauvisage could, in 1881, only state: "The Malays tried to make their forests produce as much material as possible which they could sell to Europeans as gutta-percha (naturally not without having it adulterated), at the same time the Europeans undertook researches in other directions. The manufacturers, merchants, travellers, scientists, and governments looked out for the original supply of gutta-percha, and they searched not only the inter-tropical zone, but looked also for other not yet dis-

covered Sapotaceas. This period of investigation has not yet been concluded. A large number of still imperfect discoveries have been made in all parts of the globe without arriving at the expected practical result. Scientists have discovered trees in the Indian Archipelago, in Indo-China, Hindustan, tropical Africa, Guiana, Brazil, etc., which supply a latex containing a more or less good quality of gutta-percha; the physical and chemical properties of these products have not yet been fixed. Any number of substances are offered to manufacturers as gutta-percha. These products reach their destination through the hands of civilised or native traders who know nothing of the geographical origin, or do not wish to disclose it. The variety of these products is so great that no standard of properties could be fixed by which it could be recognised on the different markets. . . . Every endeavour to get a retrospective view of the trade proved futile. To clear the matter another road must be chosen, and instead of fixing the origin and properties of the product from its first sources, a backward journey from the latest points has to be taken. I have tried it, but did not succeed. Still, a result in this direction is not impossible. It will require long years of hard work and the co-operation of many disinterested and enlightened men."

The difficulties of Dr. Beauvisage in 1881 have already been lessened, and we have to thank many others besides him; and since the time of Montgomery, Lobb, Bentham, Hooker, Oxley Wight, De Vriese, Burcke, Pierre, Seligmann-Lui, Brau de St. Paul, and Sérullas, the discoveries have mainly been made by Heckel, Schlagdenhaufen, Jungfleisch, and Leo Brasse. The last named has cleared the air of many misconceptions, and classified gutta-percha in a quite remarkable article in the periodical *La Lumière Electrique*, which made it almost possible to fix the botanical origin of the gutta plants. Owing to his many years of practical experience of the needs of production, he has also grasped the proper point from which these must be viewed. He makes this quite clear in saying: "Nobody has yet formulated the question properly. It is not a matter of a single good kind of gutta-percha with which we have to deal, but with many good kinds, each of which is suitable for a particular purpose." In the course of the treatise he shows the way leading to enlightenment, and supplies a valuable document in which the names of all the kinds are given. He establishes the fact that at the beginning of the submarine

cable industry sufficient gutta-percha was to be had, and that only good qualities were used, which could only have been produced from fully grown trees. Continuing, he states: "Even at that time several gutta qualities were already mixed, and this can easily be proved. Several factories have still in use their old apparati for cleaning gutta-percha, but these are inadequate for cleaning the product of the Isonandra, especially if the quality has not been mixed with a more plastic material. The good quality became more rare, inferior kinds were added, and, not quite to exhaust the good material, its use was restricted to the utmost, and it led to the tapping of young, hardly productive trees. Gutta-percha of the first quality was so rare, and its price had risen so high, that the 'Elektrizitaets Kongress' of 1881 had to recommend a rational growing of gutta plants as absolutely imperative. Seligmann-Lui undertook researches on the east coast of Sumatra and the west coast of the Malayan Peninsula; Wray went to the west coast of Perak, and Burcke searched amongst all the gutta plants of Sumatra. Sérullas went with Seligmann-Lui, and discovered, in 1871, in the ravine of Boukett-Timah, for the second time, the *Isonandra Hooker*.

"All this prospecting was in the same circle. Seligmann-Lui and Burcke gave the *Dichopsis oblongifolium* as the best gutta plant, to which Wray added the *Dichopsis pustulatum*, and Sérullas found *Dichopsis Gutta* (*Isonandra Gutta*). It is a pity that all the researches were restricted to Malacca, but the produced gutta has not been of the best, and the Isonandra supplies only a very small quantity of latex. There must be still other plants which supply a richer and superior gutta, and it was the desire of Leo Brasse to prove this. If the industry were in future only dependent on the *Dichopsis* or *Palaquium Gutta*, *oblongifolium* or *pustulatum*, a change of methods of production would be required, and the results would not be welcome. But if the hitherto supplied good qualities can be produced in time to come, it is to be hoped that the future submarine cables will not be inferior in durability to the present ones."

It is remarkable that the caoutchouc and the gutta-percha plants do not grow side by side; the gutta-percha zone is, on the contrary, very restricted, and cannot compare with the caoutchouc zone. The latter is to be found from 30 degrees northern to 30 degrees southern latitude, in a girdle

round the globe; but the gutta-percha plants (putting aside an inferior or pseudo-quality found in India and at the Cape) are found only between the 6th degree northern to the 6th degree southern latitude, and from the 99th to the 119th degree eastern longitude. The territory includes thus 12 latitudinal and 20 longitudinal degrees, or a total area of 1,114,000 square miles; but only 40 per cent. of this is land, mainly on the southern part of the Malaccean Peninsula, about two-thirds of Sumatra, the whole of Borneo, the Riouw and the Lingga Archipelagos, and the Banka and Billitan Islands, mostly British and Dutch colonial possessions.

The gutta-percha trees on the closely situated Java, Celebes, and Philippine Islands, cannot be counted as belonging to the native flora. This may seem very strange to the observer, but geological conditions explain the reason. It is believed that Sumatra, Java, and Borneo were in former times directly connected with the Asiatic continent, and that they separated only after many centuries owing to geological convulsions which submerged parts of the land and divided the whole in parts. It has been ascertained that a submarine earth formation exists on the coasts of Sumatra and Java, which at a very great depth diminishes, entering the Javanese Sea through the Straits of Bali. It divides also Celebes from Borneo, passes Borneo, and passes then towards the Sulu Islands and a part of the Philippines. This earth formation formed a division for the vegetable and animal world. On the oceanic side neither sugar-palms nor teak trees, neither ferns nor orchids and mosses, which flourish in Indo-Malaya, are to be found; the tiger and many birds which have their homes in the woods of Borneo, Java, and Sumatra are also strangers. The same may be said of genuine gutta-percha plants.

The districts on both sides of the submerged territories belong in a word to different biological worlds. The attached map, little altered from that which Seligmann-Lui published in 1883, in the *Annales Télégraphiques*, gives the districts in a demarcation line. A glance at the map may seem to disprove the previous statements, as Java is included in the demarcation, and gutta-percha trees cannot be found on the island. The same is true of a part of the Philippines. Geological investigation offers an explanation, at least a very acceptable hypothesis. Obach says:—

"After the Malayan fauna and flora had been existing for a

time on the Asiatic continent, and probably during the latter Miocene period, first the Philippines and afterwards Java were separated from the continent, when Borneo, Sumatra, and the Malayan Peninsula were still connected with it. At that time the native Sapota plants were not yet sufficiently differentiated to produce a particular species which could supply a gutta-percha latex. When the submersion became deeper, during a later period, cutting off all direct connection with the mainland, the differentiation had become a fact, and the gutta-percha trees remained a property of the islands where they originated."

However this may be, it is certain that the gutta-percha plants are restricted to this comparatively small district. It cannot be maintained that other territories in the same latitudinal position to the equator are not able to produce such plants, since the climate and conditions of each may well permit the cultivation after a careful transplantation, and an equally good quality of gutta-percha may be the result. This point must now await further explanation in another part of the book.

Most of the gutta plants are to be found under the Sapotaceæ, plants belonging to the gamopetal Dicotyledons. The Sapotaceæ are trees and shrubs of the tropical zone, which usually contain much latex, and the latter secretes a gutta-percha. The leaves are coriaceous and entire. The middle-sized and androgynous flowers consist of four to six sepals, a four to six lobulate bell or crown-shaped corolla, four or more stamens, and a multilocular ovary with a short pistil. The fruit is a berry, generally with a rich supply of pericarps; the seeds have often a long and broad hilum. The family of trees is divided into Bassieas (Illipeas), Lucumeas, *Mimusopeas*, Bumelieas, and Chrysopheas. Under the many kinds of Sapotaceæ the genus supplying the Dichopsis (also Palaquium or Isonandra) gives the best gutta-percha plants. The most important are:—

(1) *Dichopsis Gutta* (Th. Lobb, Benth., Hook.) or Palaquium (Burcke) or *Isonandra Gutta* (Sérullas).

(2) *Dichopsis oblongifolium* (Beauvisage, Burcke), also *Palaquium oblongifolium* or *Isonandra oblongifolia* (Brakude, Saint-Pol-Lias, Teysmann). Also the *Dichopsis* or *Palaquium borneense* (Teysmann), the *D.* or *P. Treubii* and its variety *P. parvifolium*.

Following the Dichopsis, others must be mentioned :—

(3) Payena, and

(4) Several Bassia kinds.

A short botanical description of the plants and a few of their peculiarities and conditions of cultivation must be given.

1. *Dichopsis Gutta*, identical with the *Palaquium* and *Isonandra Gutta*, was the first known of all gutta plants, and

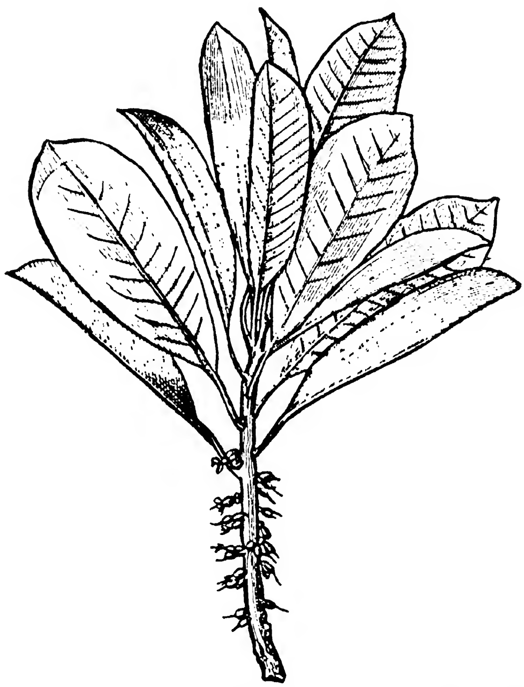


Fig. 16.—Dichopsis Gutta (Palaquium Gutta; Isonandra Gutta).

takes, in the history of gutta-percha, the same place as the *Hevea guyanensis* in that of caoutchouc; both of them are an old type, and are, owing to rarity, of little consequence. Burcke and Serrulas have given detailed descriptions. The stem is cylindrical, fully grown when thirty years old, and has then a circumference of 3 feet (about 7 feet above ground). The total height to the crown is about 43 to 50 feet. The leaves of young trees are 8 to 9 inches long, and in the middle 2½ inches wide;

fully grown trees have only leaves of 2 to $2\frac{1}{4}$ inches. Form and shape of leaves change with age, and many botanists have been thus misled, and have taken older and younger trees to be different specimens. The petiole measures up to $1\frac{1}{2}$ inches, the flower $\frac{1}{2}$ inch, the peduncle $\frac{1}{5}$ to $\frac{1}{3}$ inch. The flowers stand in clusters of six, forming a bifurcated umbel, in the middle of which is a mark left by the last generation. The inflorescence has crosswise arranged stipules, the notched calyx consists of three outer parts, which are tomentose and tunicated. The twisted sexipartite corolla is deeply notched; the system of stamens has twelve filaments, six larger ones opposite the six parts of the corolla and six smaller ones standing alternately. The ovary is sexilocular, the pistil is hollow and obconical or the top. The young fruit is conical, egg-shaped, and 2 by 2 inches in size, surrounded by the six recognisable parts of the calyx. The seed corn is oblong, pointed on top, and $\frac{3}{4}$ by $\frac{1}{2}$ inch in size. It has a tomentose base, resting in a sticky perisperm.

Sérullas recognised five different trees in the Malayan forests which may be mistaken for the *Isonandra Gutta* by their leaves and latex; confusion with other Dichopsis kinds is not likely, as their gutta ranges in quality below that of the Payena Lerii (gutta Sundeck), which Sérullas declares an adulteration. He believed only in the *Isonandra Gutta* as far as material for cable production was concerned, all others were considered inferior. The *Bassia Parkii* and the *Mimusops balata* gave only negative results, and the *Payena Lerii* served only for adulteration. Reporting in 1890 about the destruction of the Isonandra, the same explorer says when writing to the Académie des Sciences: "The destruction of the Malayan forests progresses rapidly without interruption. The natives cut down all the trees, even the smallest, and forty years ago all increase and growth stopped. The best qualities of gutta-percha are rare and nearly extinct, and those which have taken their place will meet that fate fifteen years hence. The Malayan export markets do little business, and the Dutch Indian plantations meet with little success, as the quality is inferior. . . The Isonandra has become rare, but it has not yet died out. On the Chasserian estates and in Boukett-Timah, where Th. Lobb found, in 1847, the Isonandra, I still saw in 1887 fully-grown trees, but exploitation had ceased thirty years before, as the species was considered extinct. Only one kind of tree related to the others

exists here, which Hooker called *Isonandra Gutta* in the *London Journal of Botany.*"

The *Isonandra gutta*, the best gutta-percha plant, meets the fate of the *Hevea guyanensis*, and as the latter has found a substitute in the *Hevea brasiliensis*, the former has been supplanted by the

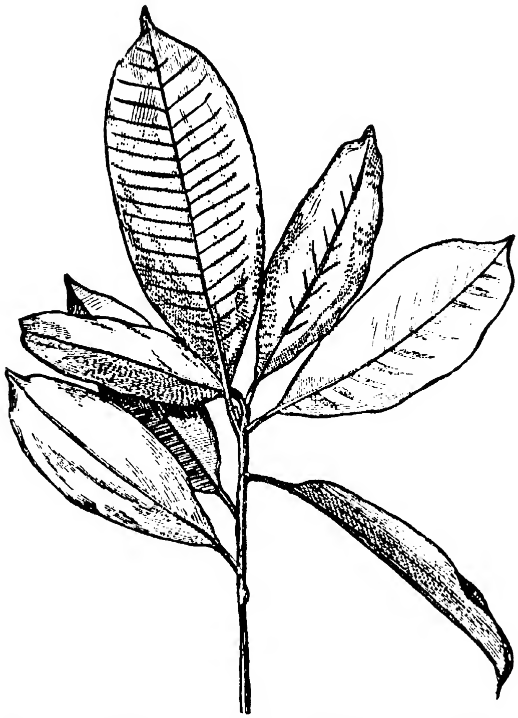


FIG. 17.—Dichopsis oblongifolium (Palaquium oblongifolium).

2. *Dichopsis oblongifolium*. After the gutta-percha from the Dichopsis gutta comes, according to the views of the explorers, the *Dichopsis oblongifolium* quality. Seligmann-Lui found the tree on the east coast of Sumatra, and Brau de St. Pol-Lias, in Perak (Malacca). The colony of Bloran in the Djambon district in Sumatra had 77 trees in 1884, a remnant of 400 planted in 1856. These came from a 2,000-tree plantation on the Bornean west coast, which trees were in 1886 divided amongst the farmers. The best trees grow on the low moun-

tain ranges and hills out of the inundation districts; the less stagnated water is near, the better is the cultivation. The tree is very sensitive to its station, and if the place is badly chosen it will soon decay. Experience has proved this in Borneo, where the Colonial Government entrusted farmers with plantations.

Gutta-percha produced from the *Dichopsis oblongifolium* is excellent in quality and durability. Free from wood and bark,

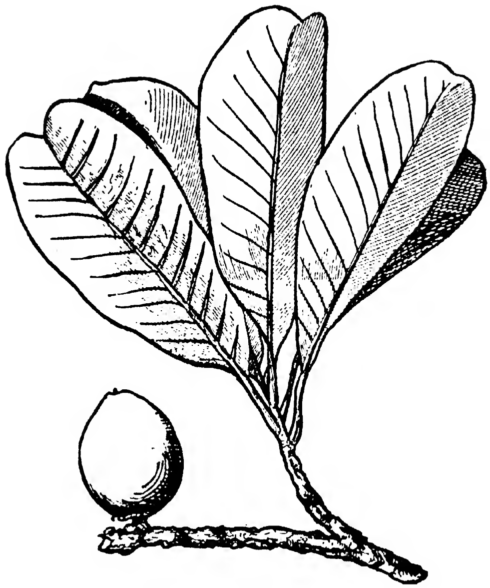


FIG. 18.—Dichopsis borneense.

it is very tough, and so flexible that it can be folded without breaking. Dipped in hot water it can be kneaded and formed without becoming sticky, and it regains the old firmness as soon as it becomes cold. The colour is a tinge between red and dark brown. Like all kinds of gutta the latex remains milk white as long as not mixed; the brown colour is caused by adulteration with wood and bark, which give the colour when the gutta is boiled and cleaned.

The *Dichopsis borneense*, the *Dichopsis Treubii* and *parvifolium*, also the *Palaquium vrieseanum*, seem only to be botanical varieties, which show no differences in the gutta-percha.

The *Dichopsis calophylla* (Benth. and Hook.) seems to be the Mayang Batou mentioned by Seligmann-Lui; it supplies a lighter, redder-coloured gutta-percha, less fine and inflexible than that from the *Dichopsis oblongifolium*.

The *Dichopsis selendit*, called by the Malayans, according to Seligmann-Lui, Mayang Korrik, and according to Burcke, Njatveh selendit, and known in Sumatra as Halaban, supplies

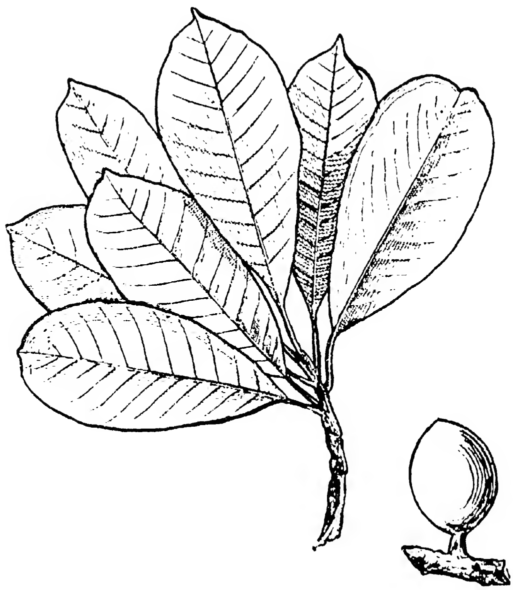


FIG. 19.—Dichopsis Treubii.

a very inflexible gutta-percha, quite unsuitable for cable production. Mixed with other qualities it can be used for various purposes. The Mayang Djerinjin and the Mayang Kartas are nearly identical varieties; the product of these shows the same advantages and disadvantages as that of the *Dichopsis selendit*.

The *Dichopsis krantziana* is a tree which the Cambodia natives call Thior, and the Cochin-China natives Chay; botanically it resembles the Selendit gutta. The produced gutta-percha is very inferior, and even when mixed it is hardly of any use. That marked botanical connection should be associated with great dissimilarity between the products of the

closely allied plants is explained by the climatic differences, and it substantiates the remark at the beginning of the chapter that only a small and restricted zone has all the needed requirements for the successful production of the gutta-percha for industrial purposes.

The Dichopsis pustulatum has been found in Perak, and is

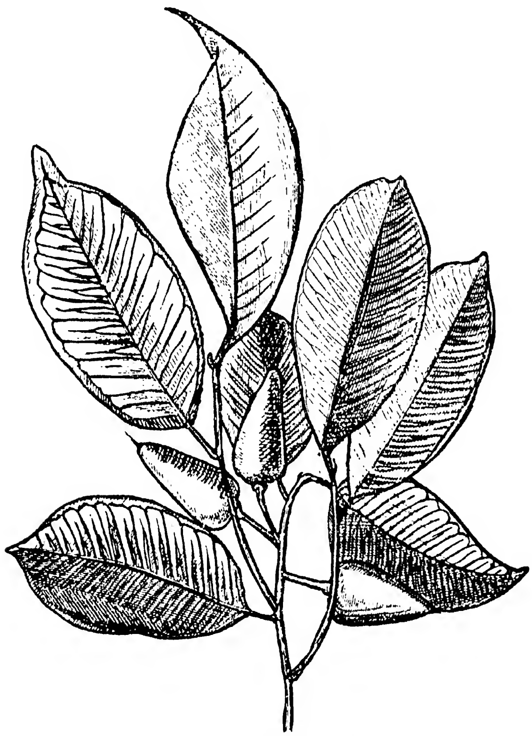


FIG. 20.—Payena Lerii.

now cultivated in Ceylon as a gutta tree. Detailed descriptions are lacking, probably because the English do not think it advisable to acquaint the world with the results, but to use the fruits of protracted experiments for their own benefit.

3. The genus Payena supplies only one gutta-percha-producing tree, the *P. Lerii*, discovered by Brau de St. Pol-Lias in Malacca and classified by Beauvisage at Paris as identical with the *Keratophorus Lerii* found by Hasskand. Malacca is with-

out doubt its home. The *Isonandra benjamina* of De Vriese is also, according to Burcke, the same plant as the *P. Lerii.* The small, thick, and tough leaves look as if they were covered with varnish, and when young they have a reddish tinge. The flower is white, the fruit fleshy, and with a horn-like cover; it is sweet and is eaten by the natives. The *P. Lerii* supplies a nice red gutta-percha similar to the Njiatoch Merah, but the product is sold under several names. On the west coast of Sumatra they call it Njiatoch Balambringin, and on the east coast, Sundeck, Sundeh, or Sundi; in Soupayang it is Sandai or Suntai; but these names must not be taken for gutta-Souni, a mixture of several kinds of gutta-percha. The *P. Lerii* grows on the plains of Padang (Sumatra), in Banca, Riouw, Amboine, and Malacca; in Assaham (Sumatra) it is rare, but plentiful in Siak (also Sumatra). The gutta is often mixed with an inferior quality called Bouhabalam. The *P. Lerii* and also the Bouha-balam tree grow in the lowlands; about 500 feet over sea-level it is replaced by the *Palaquium oblongifolium.* The *P. oblongifolium* requires a dry ground, but the Bouha-balam is a plant of marshes and swamps. The *P. oblongifolium* is sometimes called Bringin or Waringin, to be traced back to the similarity of the leaves with the Waringin (*Urostigma benjaminum*).

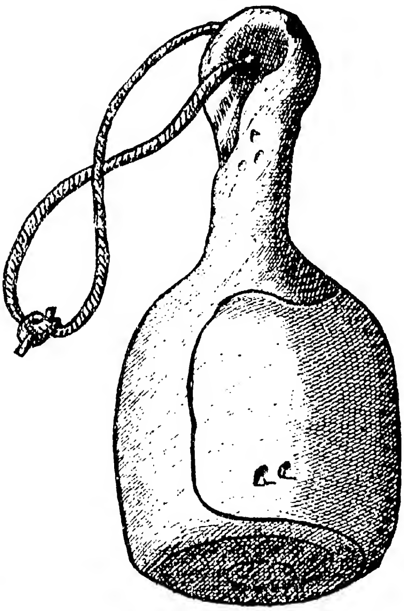


FIG. 21.—Block of Sundeck Gutta.

4. Of the Bassias the gutta-percha tree is the *Bassia Parkii*, which Professor Ed. Heckel of Marseilles has examined, reporting as follows (1885):—

"The genus Bassia includes several kinds of very large trees

which have their homes in India and Africa; the pressed seeds supply a fatty substance which finds industrial use as Illipe oil. Until now it was not recognised that a kind of this genus, the African *Butyrospermum* (*Bassia*) *Parkii* (Kotschy), produced also gutta-percha. The natives call the tree Karite or Ghee; the butter-like fat comes as Galam-Bambouh, or Ghee butter, also as Karite butter in the trade, and is an important article

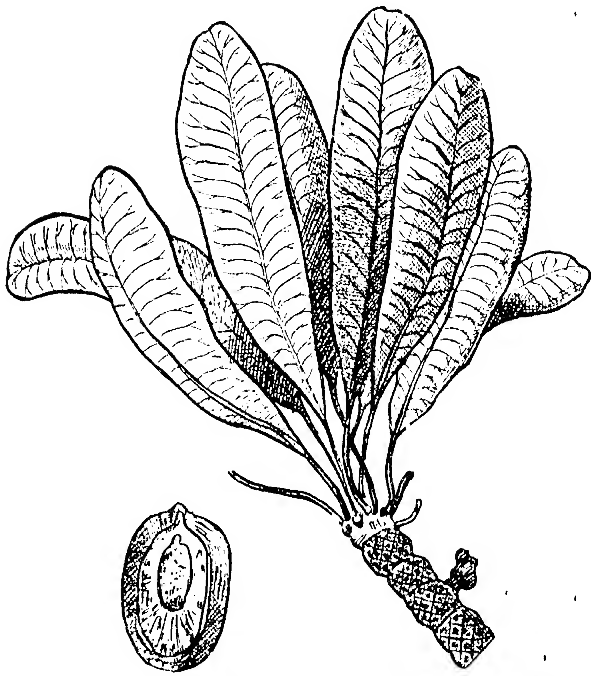


FIG. 22.—Bassia Parkii.

of food in Africa. In Europe it is mainly used for soap production, and owing to the contained stearine it is much appreciated by candle-makers. The *Butyrospermum Parkii* (Kotschy) reaches a height of 30 to 33 feet and a diameter of 6 feet, it branches like an oak and contains much latex, which coagulates to gutta-percha. The leaves are entire, thick, petiolate, and have stipules; they stand in clusters on the ends of the strong, smooth, and wrinkled branches. The petiole is first pilose then smooth, and 2 to 3 inches long. The stipules are lanceolate, about a half-inch long, and on the back silky.

The leaf is oblong, cuneiform, or round on the bottom; when fully grown it is flat on the top, strongly pilose on the back, and has 20 to 25 open ribs. The flowers come as umbels out of the axillas, and are on top of the branches; the peduncle measures an inch or more and is at first covered with downy hairs containing iron. The bell-shaped calyx has a short tube and is mostly split in eight longitudinal parts, of which the outer four have the down. The corolla is as long as the calyx and has a split tube like the latter. The stamens are enclosed. Opposite each part of the corolla is a stamen, the anthers are long. The ovary is globular and octafid or decafid. The pistil is thin and small, of varied length, and sometimes enclosed in the corolla. The fruit is an oblong berry, which contains one seed corn covered with thick seed lobes. The seed corn is large and is in a flat, tunicated, chestnut-coloured capsule. The whole fruit is of nut size, fleshy and palatable."

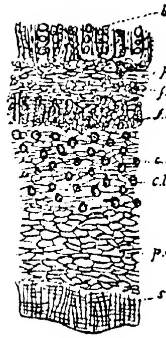


FIG. 23.—Bassia Parkii.
s. = Corky tissue.
p.c. = Bark-parenchyma.
f.l. = Latex-canals, milk vessels.
c.l. = Bast fibres.
p.l. = Bast parenchyma.
b. = Wood.

De Codolle describes the plant as *Bassia Parkii*, Kotschy as *Butyrospermum*, and Roxburg as *B. butyracia*. Its home is in Upper Guinea, in the kingdom of Bambara, where Mungo Park found it first on the Niger, in Nupe, in Jeba, etc. D'Irving and Barter found the plant on the Nile at Abbeokuta and in the near-lying districts of Gondokoro, Djur, Kosanga, near Niams-Niams, and in Madi.

The home of the *B. Parkii* can now be fixed a little closer. The Karite tree is widespread in the valleys of the Upper Niger, the Bakoy, the Baoulé, and their branches; in Beledonga, Fouladougon, Manding, Guenickalaris, etc., are large forests of them. It grows wild in glens and in silicious and ferriferous soil.

If a cut of a branch of the *B. Parkii* is examined the close-lying milk veins can be seen in the midst of the parenchyma of the bark, which is only covered by a thin skin from the outside. The milk vessels can easily be reached by cutting, and the same can be said of the caulis. But if caulis and branches are grown together, a very firm and hard liber forms in the bark-parenchyma. The liber grows quickly and protects the milk vessels

which rest on the inner side of the wood. The milk veins can be reached by a deep cut with a strong instrument. This abnormal growth is found in all Bassias and makes the collection more difficult, but even when all hindrances have been overcome the produced latex is not by a long way equal to the product of the Isonandra.

The real gutta-percha producers of the Sapotaceas have now been mentioned as far as they are known, but that does not exclude others. Not all the known plants have been properly examined, and no doubt there are others of which we know nothing. Borneo has several species in the herbariums at Buiten-Zorg and in Saigund, but nobody has ever seen them growing, and those of the Malayan east coast, especially of Pahang, have never been scientifically described.

Schematic Synopsis of the

Family.	Genus.	Variety.	Scientific Synonym.	Local Name.
Sapotaceæ	Palaquium or Dichopsis	Pal. Gutta	Isonandra Gutta, Dich. Gutta	Gueutha Tuban-Merah
Do.	Do.	Pal. oblongifolium	Dich. obl.	Mayang Doerrian, Njatoch-Balam-Tembaga, Nj. Bal. Sirah, ,, ,, Socson (in Sumatra), Nj. Bal. Doerrian, Ka-Malam-Paddi (in Borneo), Guetta-Taban-Merah (west coast of Malacca)
Do.	Do.	Pal. borneense	Dich born.	...
Do.	Do.	Pal. Treubii and variety parvifolium	Dich. Treub. and variety parvifolium.	Mayang Kapoer, Dadan, Getah-Poetih
Do.	Do.	Pal. vriesenum	Dich. vries.	Njatoeh-Bindaloe

Besides the Sapotaceas there are several other plants of the Asclepiadeæ, Apocynaceæ, and Euphorbiaceæ, which are mentioned as gutta plants. Their product is more an inferior, little elastic caoutchouc than gutta-percha. The plants are :

1. ASCLEPIADEÆ.

Cynanchum viminale (Hindustan)
Calotropis gigantea.
Asclepias acida.

2. APOCYNACEÆ

Alstonia scolaris (Hindustan).

3. EUPHORBIACEÆ.

Euphorbia cattimando (Hindustan and the Cape).
,, nereifolia ,,
,, tortillis ,,
,, tirucalli ,,
Maccranga tomentosa ,,
Pedilanthus tithymaloides ,,

Principal Gutta Plants.

BOTANIST AND EXPLORER.	ORIGIN.	NOTES.
Lobb, Oxley, Hooker, Bentham, Burcke, Brook, Seligmann-Lui, Baillon, Sérullas, Beauvisage	Singapore (mountainous part, on Chasserian Estate, in the glens of Boukett-Timah). Borneo?	Seems to have supplied the first and best gutta-percha. Only few trees can now be found, and the supply is exhausted.
Seligmann-Lui, Vesque, Beauvisage, Brau de St Pol-Lias, Teysmann, Burcke	In the whole of Sumatra (especially east coast in Loobe-Along), Lampong, south and south-west of Borneo (Banjermassin and Pontianak), Isle Riouw, Malacca, Perak	This is now the best gutta plant. Balam-tembaga means copper-yellow leaf. The tree requires moisture, but little light. The leaves contain calcium,oxalate-Latex ; abundant, colourless ; transparent, colourless, owing to the alkalies.
Teysmann, Burcke	Borneo	These three are varieties of Pal. obl. The quality of the gutta is the same.
Burcke	Isle Banka, Deli, Riouw	
Do.	Sumatra (Mant Sagoh)	

Family.	Genus.	Variety.	Scientific Synonym.	Local Name.
Sapotaceæ	Palaquium or Dichopsis	Pal. callophyllum and variety quercifolium	Ison. costata „ chrysonata „ chrysophylla „ oblongifolia	Mayang-Batou, Njatoeh-Djankar Njatoeh roepoei. Toendjoeng.
Do.	Do.	Pal. acuminatum	...	Balam soesoe
Do.	Do.	Pal. pisang	...	Njatoeh roepoei
Do.	Do.	Pal. selendit	...	Halaban-Njatoeh-Selendit, Mayang-Korsick, Mayang-Sikkum, „ Djerinjin, „ Kartas
Do.	Do.	Pal. Njatoh	...	Njatoeh
Do.	Do.	Pal. pistulatum	...	Do.
Do.	Do.	Dich. elliptica	...	Pauchontea
Do.	Do.	Pal. kranziana	...	In Cambodge: Thior In Cochin-China: Chay
Do.	Payena	Payena Lerii	Keratorpharous Lerii, Ison. benjamina, Azaola Lerii	In Sumatra: Njatoeh-Balam-Bringin, „ „ Waringin, „ „ Sundeck, „ „ Soendai, „ „ Sandai, „ „ Soentai, „ „ Pipis, Balam-Tandjong, „ Tjabee, „ Tandock, „ Troeng, „ Santé In Borneo: Njatoeh-Ka-Malam In Banka: Koelan In Riouw: Balam-Soentai, Ranas In Malacca: Gutta-Selendit, Getah Sundeck

Botanist and Explorer.	Origin.	Notes.
Benth. and Hooker, Pierre, De Vriese, Teysmann, Vesque, Seligmann-Lui	Borneo	Supplies a light and more reddish gutta; the product is less fine and strong. According to Vesque the Mayang-Batou is similar, but not identical with Pal. collophyllum. The former can stand a drier soil and more light than Pal. obl.
Burcke, Boerlage	Deli	Probably identical with Pal. quercifolium.
Burcke	Borneo	...
Seligmann-Lui, Burcke, Vesque	Sumatra, Malacca	Very hard gutta; not suitable for cable production. Can stand dry soil, but little light.
Teysmann	Java (prov. Banjerang)	Do.
Pierre	Perak (Ceylon)	Successfully cultivated by the English.
Do.	Wynaad, Coorg, Travancore (Brit. India)	Gutta horn-like, and when cooling, brittle.
Do.	French Protectorate in Indo-China	Supplies inferior gutta-percha, likely owing to unfavourable climatic conditions.
Benth. and Hooker, Miguel, De Vriese, Seligmann-Lui, Vesque, Beauvisage, Burcke, Teysmann, Tromp, Hasskarl, Brau de St Pol-Lias	Sumatra (Padang, Assahan, Siak), Banka, Borneo, Riouw, Amboin, Malacca	Owes the names Bringin and Waringin to similarity of leaf to that of the Urostigma benjaminum, in Malayan called thus. Product brown in all mixtures, coming as raw gutta-percha on the market. Not equal in quality. Trees are earlier productive, as Pal. obl. All tissues of plant contain a substance which turns black under the influence of alcohol. Cultivated by the English in Pardenia and Hemeratgoda.

Family.	Genus.	Variety.	Scientific Synonym.	Local Name.
Sapotaceæ	Payena	Payena macrophylla	Kakosmanthos-macrophyllus	Getah-Moendirig
Do.	Bassia	Bassia Parkii	B. Butyrospermum, B. Niloticum, B. Butyracea,	Karite-tree Ghi-tree Saga
Do.	Payena	Pay. rubro-pedicillata	...	Melali
Do.	Do.	Pay. latifolia	...	Sangai
Asclepiadeæ	Cynanchum Calotropis, Asclepias	Cyn. viminale, Cal. gigantea, Ascl. acida	...	...
Apocynaceæ	Alstonia	Alst. scolaris, A. grandifolia, A. costulata,	...	...
Euphorbiaceæ	Euphorbia, Macaranga, Pedilanthus	Euph. cattimando, E. nercifolia, E. tortillis, E. tirucalli, Mac. tomentosa, Ped. tisthymaloides,	...	...

Botanist and Explorer.	Origin.	Notes.
De Vriese, Teysmann, Hasskarl, Miquel, Beauvisage, Burcke	Java (prov. Bantam)	The gutta-percha is inferi to the afore-mentioned.
Linné, De Candolle, Roxburg, Kotschy, Guibourt, Baucher, Heckel, Schlagdenhaufen, Mungo Park, Gallieni, Schweinfurth	Upper Guinea, Bambara, Upper Niger, White Nile, on the Niams-Niams, the Bakay Valley, in Baoulé, Beledongo, Feladongo, Mandiarg, Guenikalaris, by the Bougos	According to Heckel, the Bassia has a future in Africa, —will be the competitor of the Palaquias of the Sunda Isles.
Van Romburgh	Borneo	...
Burcke	Do.	...
...	British India	Still very little known. Supplies a product which is more a bad caoutchouc than real gutta-percha; it can only be classified as a pseudo-gutta-percha.
	Do.	
	India and Cape Colony	

The foregoing tabulated synopsis of gutta-percha plants contains undoubtedly a few inaccuracies, because botanists have, as already stated, mistaken the age of the leaves of what proved to be one and the same plant.

Just as little as is known about gutta-percha producing plants is known about the influence of climatic conditions on them. Seligmann-Lui is the only one who has considered the point, and an extract of his observations will therefore be useful.

"The Sunda Islands were created by volcanic eruptions, of which they still show direct traces. In the centre they are mountainous and are flat towards the sea. During the rainy period the rivers receive large quantities of water which rushes quickly down the valleys, raising up the river beds in the upper regions, and carrying soil and clay to the lowlands, where they settle on the banks. The alluvial deposits grow from day to day and make banks on the seashore, the banks in course of formation lying still under the sea level where their form changes permanently; these are moving swamp islands covered with swamp plants, especially water palms. The older alluviations have been dried in the sun and become firm territory over the water-line. On these fruitful portions of the islands the natives have settled down and Europeans have founded their plantations. In Deli and Langkat they grow tobacco, in Benkalis, manihot and cinnamon, in Palembang on the west coast, sugar, coffee, and pepper. Farther inland, where the rivers are embanked and inundations prevented, where rocky glens take the place of clay soil, the vegetation changes, and instead of plantations there are forests, the home of the Mayangs (gutta trees). Numerous rivulets, which do not dry up in the hot period, keep the soil fresh and moist. A dry season is hardly known in the Malayan Archipelago, with its seven feet of rainfall per annum, and after the rainy winter there are always showers to supply fresh water. The territory is not so high as to have changes of temperature caused on this account. On the coasts of Java and Sumatra the average temperature is never under 77° F. during the winter. That the Mayangs can only grow here is not certain, but everywhere where Murton found them the conditions were alike."

This information about the geographical position of the Mayangs left the other explorers of the gutta countries little

hope, and outside the zone of 3 southern and 5 northern latitude no wild-growing gutta plants have yet been found.

Pierre's researches in Cochin-China and Cambodia led to no remarkable results, because the Thior (*P. krantziana*) can hardly be called a gutta-percha, and the others mentioned by him have also no similarities. Seligmann-Lui heard that an Englishman in the Siamese service had found on the west coast of the Gulf of Siam (13 degrees northern lat.) a gutta-percha tree, but it was only the Borneo rubber, a caoutchouc also found in Burmah and Pegu. The King of Pegu, an expert on the point, confirmed the contention that no gutta-percha trees grew northwards of Trigano. As the trees cannot stand transplantation to other climates, where they degenerate and supply an inferior product, it seems impossible to find any means of acclimatisation, and even cultivation in the given zone presents very great difficulties.

Seligmann-Lui has already stated it is not only a characteristic of gutta-percha, that it is plastic and withstands electricity, but also that it does not change. Since the advent of the cable industry, the endeavour has been made to improve insulation, and the mixing of gutta-percha has often gone far beyond the requirements. None of the artificially improved products equal in durability the pure gutta, and in all the laboratories the experiments of the past will only be repeated. Should a kind of gutta-percha offer advantages it should be cultivated, but it should not be forgotten that the real effect and value of the product must first be proved. The sorts which have proved their value should not be forgotten, and Seligmann-Lui mentions amongst these the Gutta Derrian or taban. When pure it is white, but it is mostly coloured red by foreign substances; the first glance proves that it is gutta-percha, and it is the best-known sort which has been exported. Only when the Gutta Derrian was exhausted the other qualities were taken up, and in the second rank comes the Gutta Sundeck and Gutta Batou, which range equal in the trade with all the others. Gutta Sundeck is also white, and when cut is smooth, glossy, and ivory-like. Most Sundeck put on the market has red tinges, owing to the circulation of the latex between wood and bark, where it mixes with a red colouring sap of the outer bark. This gutta-percha is less plastic than that of the Derrian Gutta. Gutta Batou is lighter and more red than Derrian, has a finer fibre, and is probably also less strong. Gutta Belouk and

Gapouk, both known to the trade as Gutta Pouteh (white), are inferior qualities, and have already some similarities with the Bouhabalam gutta, a worthless quality coming from the flat islands or swampy plains. After a short while the material becomes brittle and falls to dust. Only after further investigation will it be possible to say if the change is simply a physical one, or if oxidation or resin-formation progresses quicker than in other gutta-percha qualities. It is also necessary to find if the boiling (of which more has still to be said) has an influence on these changes, and if it can prolong the use, or if cable manufacturers have to leave these qualities altogether out of account. They would still remain useful for other industrial purposes and requirements.

The conclusion from the afore-mentioned account must be that it would pay best to cultivate Mayangs which produce the Gutta Derrian, and try the transplantation of this species. With regard to the other qualities, continued and detailed researches are necessary. Not only the electrical properties and the possibilities of insulation, but also all the other physical and chemical properties require careful elucidation. It is necessary to ascertain if the sorts are elastic, how they behave under high and low temperatures, at what temperature they become soft, how hard they are after they have been kneaded, to what extent they withstand oxidation, if they remain waterproof under pressure, etc., etc. Only when the answers to all these questions are satisfactory, and when experience has added its testimonial, can rational cultivation of these trees be recommended. It is likely that a better product than the Gutta Derrian may be the result. When it is taken into consideration that fifteen to twenty years must elapse before a plantation supplies the first gutta-percha, and that another period of equal length is needed to prove durability, it is clear that no definite result can be proclaimed before thirty or forty years have passed. This shows that cultivation and acclimatisation of gutta-percha are very difficult and necessitate protracted labour, and before science has become clear on the point a very long time will have elapsed. All that can be said to-day is that Englishmen have investigated these points already for years, and the chosen field for experiments, Ceylon, has, on account of its climatic conditions, great chances of achieving good results. The reason for the miscarriage of the French experiments by Pierre was the unfortunate choice of a zone or terri-

tory. The same experiments in the French African colonies, nearer the equator, would most probably have had a much more satisfactory ending.

Of the German colonies Cameroon and the possessions in New Guinea would from this point of view come into consideration. According to O. Warburg, Cameroon, at least the country round the Cameroon Mountains, is particularly suitable for the cultivation of West Malayan gutta-percha trees, not only because of the equally warm temperature, but also the rainfall, heavy and distributed over the whole year, is identical in both districts. The deep volcanic soil of the primeval forests must be equally suitable for the trees when these conditions are compared with their native plantations. Probably better than Cameroon may be German New Guinea for the plantation of gutta-percha. Several species of the Sapotaceæ plants are already at home in this country, as is testified by the botanists Dr. Hollrung, Helling, Karnbach, Lauterburg, Warburg, and Weiland, but these plants do not yet supply a latex which can be coagulated into gutta-percha. A number of experiments have already been made in Cameroon, the *Payena Lerii* and the Guatemala gutta-percha of the *Tabernæmontana Donell-Smithii* being singled out for acclimatisation. Thirty-one cuttings of the former and forty-seven of the latter were supplied by the Colonial Economical Committee to the Moliwe plantations. Of the latter several developed very nicely, but the former died off after a short while. The botanical garden in Victoria (Cameroon) was not more successful, it has only seven small plants of *Payena Lerii*, whereas the one *Palaquium Gutta* has ceased to exist.

These scientific rather than practical results of experiments did not deter the Colonial Economical Committee at Berlin from searching more energetically for suitable gutta-percha plants, and in 1900 they sent the botanist Robert Schlechter to study the problem in the home of the gutta-percha plants. He received the order to find seeds and plants for Cameroon and New Guinea, to bring them himself to New Guinea, and to send those suitable for Cameroon across Europe to their destination. The first of Schlechter's stopping places was Singapore, and from here he went to Sumatra, Java, and Borneo. He searched for wild-growing gutta-percha trees, also in botanical gardens and in the plantations where they grow under proper cultivation. He collected on these excursions many thousands

of seeds and young plants (*Dichopsis Gutta*), of which he planted those selected for Cameroon for the time being in the botanical garden at Singapore, whereas he brought some of those for New Guinea to the plantations and arranged to send the rest at intervals. Seeds and plants have been bedded in suitable plantations in the German north-east districts of New Guinea; the consignment for Cameroon arrived in October, 1902, at Hamburg, whence they were sent in charge of a plantation assistant to the planting station in Cameroon.

So far the best plants only had been considered, as for instance the *Palaquium Gutta* from Sumatra and the Malayan Peninsula, but the Berlin Committee came also in possession of large quantities of Borneo plants through the Belgian Barito Society, which had imported those seed plants for sale. The botanical garden in Victoria (Cameroon) and the Molive plantation took each a few boxes of seedlings, part of which were sent at once, the rest following in the spring of 1903. The director of the botanical gardens of the Congo State at Laeken near Brussels also presented the Berlin Committee with a Ward's box of *Palaquium Gutta*, *Treubii borneense* and *oblongifolium*, of which species hitherto unknown in Cameroon were to be sent over in spring, 1903.

"We are able to maintain," writes Professor O. Warburg in the November issue of the *Tropenpflanzer* for 1902, in which he reports about the seeds and plants, "that we have found a basis for gutta-percha cultivation in Cameroon; it will now only depend on the use of the Javanese experiences and on careful experiments to develop a cultivation on a large scale."

III.—Collection of Raw Gutta-Percha.

It is known that gutta-percha is collected in Sumatra by felling the trees, and another method of collection has not yet been introduced. Very old trees have stems of three to seven feet in diameter, and on the bottom numerous offshoots, necessitating the erection of scaffolding to get at the tree; but these giants have become rare, and are only to be found where the natives have not yet exhausted the supply. The trees are only to be found in the densest parts of the virgin forests, and as the woods near the villages (kampongs) have been plundered, the gutta-percha collectors have to penetrate the forests, and they do it with surprising quickness, considering the impenetrable thicket of underwood. Where the genus of trees is doubtful, and the leaves cannot be got at, a tree is cut to fix the genus to which it belongs; but the colour of the stem, the thickness of the bark, and the hardness of the wood are surer signs for the intelligent native. If a tree has been marked as worth tapping, it is cut down and semi-circles are cut in the bark by means of an axe, at a distance of about twelve to twenty inches. Before cutting the circles, some of the natives strip the tree of leaves and branches to prevent a loss of latex. The sap collects slowly or quickly in the circles according to the kind of the tree. The latex of the *Payena Perii*, the Tuban Derrian and tambaga of Soupayang, does not coagulate directly; the latex of the *Dichopsis oblongifolia* is thicker, coagulates quickly, and thickens between the bark and the wood fibre. The bark of the open circle on a Dichopsis crumbles under the axe and becomes soft, preventing the running of the latex out of the circle.

The collection of the latex progresses very slowly in many places, and during the cutting of the circles a great part of the latex is drained off, but the native does not take the trouble to collect it in cups or vessels. Many collectors declare the out-running latex as inferior, because it is white, and red or brown is preferred and commands a better price; others give no reason for the negligence. As soon as the tree has been covered with cuts from root to crown, the latex is scraped together with a piece of iron and put into bags made of esparto grass. As soon as all the circular cuts have been emptied, the tree is done with, and another has to be chosen. It happens sometimes that the latex continues to flow and fills the cuts a second time, but this is neglected. The cuts can only be inserted on one-half of the

tree, as the other half rests on the ground and this other half cannot be reached; at least it would be too troublesome to clear the underwood for hauling or turning the tree. Thus, half of its contents exhausted, the gutta tree is left and nobody takes any notice of it, although the wood is an excellent one. In other places the tree is only valued and cut down for the wood, and no one thinks of collecting the gutta-percha. But still another result of carelessness has to be stated. Each of the felled giant trees pulls down many others, and many had also to be cut down to free the gutta-percha tree from the connecting creepers. The results of the destruction cannot be avoided and are already noticeable. Formerly the Dichopsis was only tapped when about the size of a cocoa-nut tree (3½ feet circumference), but this size is to-day rare. Full-grown trees supplying inferior gutta are to be found in larger numbers, but this is owing to the fact that the product is not in demand. Only since the superior gutta became rare (about twenty years ago) have these trees been tapped.

Léon Brasse and Seligmann-Lui witnessed several methods of preparing the gutta-percha latex. The thin latex, like that from the Payena, is brought liquid to the hut, but the thicker latex of the Dichopsis mixes with pieces of wood and coagulates to some extent during the transport. The workman picks out the bigger splinters and pieces of bark, and throws the material in a pot with boiling water, where the gutta becomes soft and can be kneaded into one compact substance. The material is worked into thin and flat strips which bring the remaining particles of wood and bark to the surface, when they are removed by rubbing in cold water, and this operation is generally repeated. The gutta is again softened, kneaded, rolled in leaves, washed, rubbed, and formed into blocks of different sizes and shapes, in which the different leaves can still be recognised. The loaf, roll, bone, and bottle shapes are to a certain degree characteristic of the district from which the material originates. Sometimes the collectors show quite artistic leanings, in the same way as is shown by the Brazilian caoutchouc collectors. They give the gutta-percha, which in this condition is more pliable than raw caoutchouc, the shape of serpents, birds, and all kinds of other animals. Gutta twice cleaned is superior, but it is not yet pure, and still contains wood particles, which can only be removed by an elaborate process later to be described. The gutta is not cleaned in

Sumatra; more often it is adulterated by additions of large quantities of pulverised bark. During the working the gutta-percha loses its colour; when the latex comes from the tree it is white, and the addition of wood and bark gives it varying colours during the boiling. The gutta of the Payena becomes yellow through the influence of the air, but the gutta of the Dichopsis colours only through the influence of colouring material during the boiling. It is stated that collectors give the gutta the desired colour to make it suitable for the market.

Unmixed gutta-percha, that is to say, all from the same kind of tree, is seldom found on the market. The collectors do not mind making up their total with the latex of other trees, should one kind not supply sufficient and their time be limited. Returned to their camp, they are still more ready to mix all in one pot. It is impossible to find samples of the several kinds by purchasing them from native traders.

The best-known mixed sort is called Balam-tembaga, when the latex of the *Dichopsis oblongifolium* forms part of it. Experience has taught the Malays which sorts can be mixed best and those which suffer by mixing, and self-interest prevents them from using these.

The collection of gutta-percha in North-West Borneo, and also in Sarawak, Pontiak, Labuan, and other places, has been described by Leys, the Consul-General of the British possessions in North Borneo. He states that the different kinds are products of varying trees, but that the pure red gutta-percha comes from the Dichopsis latex. Other trees give an inferior quality which is mixed by the natives. The red gutta-percha comes from trees 130 to 170 feet high, growing on the banks of old jungles. The method of production is as follows: as soon as the tree has been found, about 3½ feet circumference at 6 feet height, the crown is cut off, and the circular cuts are inserted in the bark at a distance of about 14 to 18 inches. The latex runs for two or three days into vessels formed of leaves or half cocoa-nuts, when the whole is placed in one pot and boiled. Some water is added to prevent the hardening in the air, by which it would lose commercial value.

Geographical and climatic conditions, age of trees, the method of collecting, the felling of the tree, and the cutting of the circular insertions, have an influence on the quantity the different gutta-percha trees supply. Expert opinion varies to such an extent that doubt in all is quite justified. Burcke

states the average supply of a full-grown tree as 11 oz.; Sérullas reports that a giant tree in Pahang gave 13½ oz.; Wray noted a 100 years old Taban-merah tree which gave 2 lb. 5 oz., and a fully grown Taban-puteh tree 2 lb. 11 oz. Logan gives the average yield of a tree in Johor as 5½ lb., and Oxley the same for Singapore as 13½ lb. Confronted with these statements are others which put the average of less developed trees at 32, and that of fully developed trees at about 100 lb. Who is right cannot be said with certainty, but one thing is certain, that the irrational methods of collection, which kill all trees, will soon diminish, if not put a stop to the whole supply.

The question how to meet the danger has interested explorers, manufacturers, and governments. E. Jungfleisch thought of improving the methods of cultivation and collecting. A test with samples of plants brought over in 1888 by Sérullas led to the expectation that other organs of the tree beside the stem contained gutta-percha, and in much larger quantities than the Malays ever thought of. Jungfleisch kept this point in mind, and he found that gutta-percha could be got out of the cells of the plants by means of solvents, and toluol has proved to be the best solvent for extraction. It dissolves the three constituents of gutta-percha (gutta, albane, and fluavile), but the other substances in leaves, bark, and wood, except a little chlorophyll, are only slightly dissolved. The following tests were made :—

(1) Leaves dried in the open air, *i.e.*, oxidation by means of fresh air.

(2) Leaves dipped in antiseptic water and then dried.

(3) Offshoots dried and stripped of leaves.

(4) Wood two years old, dried and stripped of leaves.

All these parts of trees gave considerable quantities of gutta-percha, which can be stated as

I.	2000	grammes	old dry wood	200	grammes	gutta	= 10 per cent.
II.	2000	,,	,,	183	,,	,,	= 9.15 ,,
I.	1000	,,	dried offshoot	102	,,	,,	= 10.20 ,,
II.	2000	,,	,,	211	,,	,,	= 10.50 ,,
	2000	,,	dried leaves	204	,,	,,	= 10.02 ,,
	5000	,,	not fully dried leaves	453	,,	,,	= 9.06 ,,
I.	200	,,	leaves dipped in water	21	,,	,,	= 10.05 ,,
II.	200	,,	,,	18	,,	,,	= 9.00 ,,

The high percentage gave rise to the belief that some of the constituents of the plants are dissolved with the gutta-percha, and the first glance would lead one to believe in the accuracy of this view, as the product is greenish, and has a peculiar, not bad, but somewhat overpowering smell, whereas Malayan gutta-percha is always red. The real gutta-percha is naturally nearly colourless, it colours when mixed with chlorophyll (which can easily be separated) and also with bark fibre and other vegetable products. It has been found that the gutta-percha produced by the new method is of excellent quality, which can be compared with any other, and traders and manufacturers value it very highly. More rational collection can be looked forward to, and where at present only leaves are dealt with further improvements are sure to follow. Besides this it is to be hoped that the remaining real Isonandras in the Malayan Archipelago will be better cultivated to supply a pure and unadulterated gutta-percha. To assure this and to prevent fraud, the leaves of the trees must be sent to Europe for extraction. The Malays will be quite as willing to sell the leaves as to collect the gutta-percha, and the owners of estates will be encouraged to cultivate plantations, even at the risk of a few sacrifices. Sérullas states that a thirty years old tree carries 55 to 65 lb. of leaves, which, when dry, weigh 11 lb., giving, according to the new method, 1,000 to 1,100 grammes —$2\frac{1}{8}$ to $2\frac{1}{2}$ lb. gutta-percha, whereas the same tree when felled gives only 11 oz. The Malays neglect the branches and leaves, wasting all the good material. The leaves can be gathered several times a year, and they can be taken from trees of all ages and circumferences.

The manner of extracting the gutta-percha by this method is very simple. The pulverised material, leaves, branches, and bark, etc., is heated to about 212° F., when the solvent toluol is added. A green coloured solution (owing to the chlorophyll) is the result. The direct evaporation of the solvent is not possible without injuring the product, the toluol is therefore removed by means of steam at a temperature of not more than 212° F. One part of steam takes up four parts of toluol, and the gutta-percha remains. To remove the solvent altogether the steam is left working a little longer on the stirred-up substance, heated to the above given degree.

Not only Jungfleisch and Sérullas, but also D. Rigole, Professor Ramsay, and Dr. E. Obach, have carefully studied the

production of gutta-percha by extraction, and several apparatus have been described in the "Cantor Lectures on Gutta-percha" given by the last-mentioned scientist.

The most simple of these apparatus was constructed by D. Rigole (Fig. 24), in which bisulphide of carbon is used. The leaves come into tank A, whereas the bisulphide of carbon is in the boiler B, in which it is heated and evaporated by means of a hot water bath, D. The vapours rise through the tube as in C, where they condense and run as liquid on the leaves, which

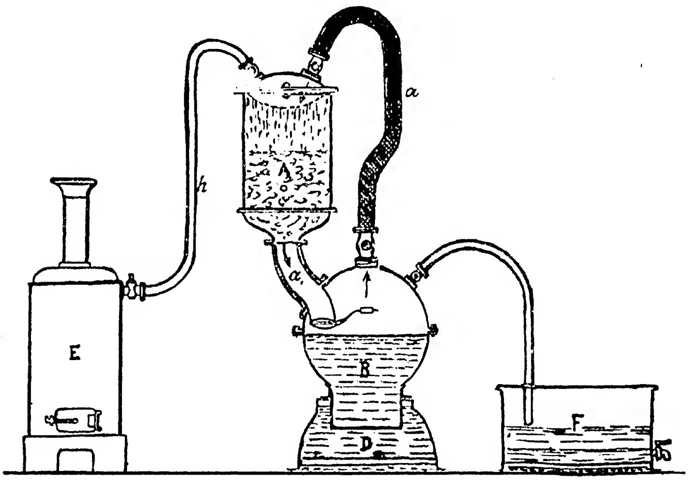


FIG. 24.

they permeate, and they return with the extracted gutta-percha through *a* to B. After a perfect lixiviation of the leaves steam is introduced from the boiler E through the tube *h* to the tank A, which steam distils the bisulphide of carbon and the solution from B to the tank F; the produced gutta-percha remains in the boiler B and floats in the condensed water. Instead of the toluol used as solvent by Jungfleisch and Sérullas, Professor Ramsay prefers resin oil, and Dr. E. Obach uses petrol-ether for the extraction of gutta-percha out of leaves, but the apparatus employed are all similar to those just described.

Latterly a mechanical method has been adopted in addition to the chemical one. The dried leaves and smaller branches

are moistened with hot water, then ground to powder in a machine and steeped in water. The gutta-percha is said to collect in a floury mass on the surface of the water, which is strained off by means of fine strainers made of copper gauze; the cream is put in warm water and afterwards formed in cakes or loaves. The method has just been tried in Singapore, with good results, it is stated. A short time ago a company was formed at Medam, in Sumatra, to exploit the method, and a factory for this purpose has been built on the Lingga Island in the Riouw Archipelago.

These tests and experiments cannot be considered as complete, and the results have to be awaited of the experiments which have been made to prove the usefulnes of the product extracted from the leaves. Only small quantities have been manufactured and a few articles made. Of the greatest interest are the results in insulating air and submarine cable lines, but many years are needed to show the full effect. There is no doubt that the gutta-percha production has reached a turning-point, on the one hand by the adoption and perfection of the methods of extraction, and on the other hand by the experiments for a more rational cultivation of gutta-percha plants and their acclimatisation in countries like Cameroon, New Guinea, and others for which they are found suitable.

IV.—Commercial Notes.

The repeatedly mentioned and meritorious work by Léon Brasse has supplied valuable material for this chapter. He took every kind of gutta-percha, and traced, as far as possible, the origin and the form in which it comes on the market, because the old-fashioned denominations, like Macassar, Singapore, Java, Sumatra, Borneo, etc., mean really nothing; they only obscure the value of the designated article. He noted also the appearance, cut, the contained foreign substances, and the properties which have to be considered from a commercial point of view, such as nerve, hardness, more or less quickness in cooling, and the quality of the obtained thread. He also fixed the proportions of pure gutta and the resins contained in the various qualities, and laid down the specific resistance in Megohm-centimètres. The noted impurities are based on the

Tabulated Synopsis of th

No.	Name.	Geographical Origin.	Form.	Appearance.	Appearance when Cut.
1	Pahang	State Pahang, on east coast of the Malayan Peninsula	Small pieces, pear shaped, about 1-2 lb.; those rectangular, flat on bottom, not more than 6¼ lb.	Yellowish, seldom reddish, mostly green tinged	White-yellowish seldom yellow-reddish; compac seldom leaved
2	Do.	Do.	Do.	Do.	Do.
3	Do.	Do.	Do.	Do.	Do.
4	Do.	Do.	Do.	Do.	Do.
5	Do.	Do.	Do.	Do.	Do.
6	Do.	Do.	Do.	Do.	Do.

results of washing. The proportion of gutta-percha and resins was fixed by Brasse as follows: He took 5 grammes of cleansed gutta-percha and dissolved them in a water bath in benzin, obtaining as a total 200 cubic centimètres liquid. Of this he took after the filtration 50 cubic centimètres pure gutta and poured them drop by drop into 100 cubic centimètres boiling pure alcohol, dried the gutta by a temperature of 225° F. by means of dry carbonic acid, and thus obtained the weight of pure gutta-percha. Another sample of 50 cubic centimètres filtered fluid was vapourised and dried as before mentioned. The difference of the two weights gave the resin contents in the gutta-percha.

The specific power of resistance to electricity is given according to a measurement obtained by a practical test with a gutta-percha insulated wire. These tests were made with all known sorts of gutta-percha, and may serve as examples for work of this kind. They have been put into table form to enable them to be more readily understood, and also for the purpose of ready comparison.

Principal Kinds of Gutta-percha.

Nature and Quantity of Impurities.	Value.	Nature of the Thread.	Proportion of Gutta-percha and Resin.	Specific Resistance in Megohm-centimetres.	Notes.
Little wood splinters, 33 per cent.	Easy to manufacture; remains long very nervy; when cooling, easily regains the previous hardness	A little shrivelled	6, 20	62, 10	... ...
Do., 25 per cent.	Do.	Do.	4, 69	16	... ...
Do., 33 „	Do.	Do.	4, 94	50	... ...
Do., 28 „	Do.	Do.	3, 89	15	... ...
Do., 24 „	Do.	Do.	5, 75	5	... ...
Do., 41 „	Do.	Do.	5, 25	28	... ...

No.	Name.	Geographical Origin.	Form.	Appearance.	Appearance when Cut.
7	Sandakan	North-east of Borneo	Loaves of 4¼ lb., in shape of a parallelepipedon, with trapezoidal foundation and boat-shaped elongation; sharply pronounced angles; formed gutta	Light yellow	White-yellowish, seldom yellow-reddish; compact, seldom leaved
8	Maragulai	(?)	Very flat loaves of about 2 lb. or less, also flat or square pressed spindles of about 6 to 8½ lb.	Whitish grey, with grey specks	Horn-like
9	Bagan	Probably between Malacca and Singapore	Pear-shaped pieces of about 4 to 6 lb., or beets of 6 to 8½ lb.	Wine-red; feels, if warm or cold, like soap	More or less rough; numerous holes, owing to insufficient connection of pieces of which the large pieces are made
10	Do.	Do.	Do.	Do.	Do.
11	Banjermassin	South Borneo	Rounded off at the ends; sticks of about 30 inches long, 4·6 diameter; also parallelepipedons of 20 to 24 inches; both sides sculptured, one side a beast and the other leaf work	Sponge-like, brown, even blackish	Salmon-coloured leaved
12	Do.	Do.	Do.	Do.	Do.
13	Kotaringin	Do.	Spindles, pointed at both ends, square section or flattened of about 2 to 4 lb.; also parallelepipedons of 6 to 8½ lb., rounded at the ends	Lighter, as Banjermassin	Salmon-coloured leaved

Nature and Quantity of Impurities.	Value.	Nature of the Thread.	Proportion of Gutta-percha and Resin.	Specific Resistance in Megohm-centimetres	Notes.
Little bark, 22 per cent.	Easy to manufacture; remains long very nervy; when cooling, early regains the previous hardness	The thread is smoother	2, 29	56	The gutta seems to be flattened before it is moulded.
The material contains no irregular shaped pieces of bark; these are regular cut, and about ½-inch; added intentionally 16 per cent.	Very hard quick-cooling gutta	Shrivelled thread	1, 27	43	... ...
Either none or few pieces of bark, 29 per cent.	Fairly hard, and nervy, quickly cooling gutta	Very smooth thread	1, 47	30	Smells of opium; difficult to clean; not unlike balata when cleaned and spun.
29 per cent.	Do.	Do.	1, 42	17	... ...
Much bark, 45 per cent.	Very hard, very nervy, quickly cooling	Shrivelled thread	4, 09	141	... ...
40 per cent.	Do.	Do.	2, 20	52	... ...
32 per cent.	Less nervy than Banjermassin	Do.	4, 82	25	... ...

No.	Name.	Geographical Origin.	Form.	Appearance.	Appearance when Cut.
14	Kotaringin	South Borneo	Spindles, pointed at both ends, square section or flattened of about 2 to 4 lb.; also parallelepipedons of 6 to 8½ lb. rounded at the ends	Lighter, as Banjermassin	Salmon coloured, leaved
15	Pekan	Pahang on the sea coast	Loaves 1½ to 2 in. thick, and 4 to 11 lb. in weight	Reddish-brown, dark plum-coloured, mouldy	Wine-red, very homogeneous
16	Do.	Do.	Do.	Do.	Do.
17	Sarawak	North-west of Borneo	The loaves, if dry, are light in proportion to their size	Spongy loaves, the surface is warty with brown bark	Yellow-reddish with white veins
18	Do.	Do.	Do.	Do.	Do.
19	Pontianack	South-west of Borneo	Blocks of 11 to 12 lb.	Very spongy, yellow-reddish, more grey than Sarawak	Like Sarawak with white or grey veins
20	Do.	Do.	Do.	Do.	Do.
21	Padang	West Sumatra	Flat parallelepipedons, carrying a stamp of origin about 4 lb., also larger loaves up to 65 lb.	Very outspoken yellow-reddish colour	Distinctly leaved
22	Sarapong or Souni	East Sumatra	Oval-shaped loaves, pointed at the ends, about 1 to 2 lb.	Surface shrivelled, earthy	Homogeneous, white-yellowish
23	Do.	Do.	Do.	Do.	Do.
24	Siak	Do.	Sticks, thicker in the middle, 4 to 6½ lb.	Yellow-reddish	Cut lighter, leaved

Nature and Quantity of Impurities.	Value.	Nature of the Thread.	Proportion of Gutta-Percha and Resin.	Specific Resistance in Megohm-centimetres.	Notes.
26 per cent.	Less nervy than Banjermassin	Shrivelled thread	4, 89	11	... ...
Few impurities, 23 per cent.	Less hard and nervy, cools very slowly	Smooth threads	1, 03	90	... ...
29 per cent.	Do.	Do.	1, 42	17	... ...
Much bark, 50 per cent.	Very good quality, very nervy, quickly cooling	Shrivelled thread	3, 23	65	... ...
45 per cent.	Do.	Do.	2, 85	125	... ...
Much impurity, 44 per cent.	Very good gutta	Do.	3, 57	141	... ...
33 per cent.	Do.	Do.	3, 02	171	... ...
Much impurity, 40 per cent.	Hard and nervy, quickly cooling	Nervy thread	2, 24	457	Cannot be used unmixe for electrical purposes.
Very pure, 30 per cent.	Superior quality, fairly hard, little nervy, quickly cooling	Very smooth thread	1, 49	137	Several mixtures made b Sumatran natives calle Souni. Contains red an white gutta in varyin quantities. Seligmann-Lu saw the following mixture made: Gutta Derrian (Dich obl.), 2. Gutta Sundeck (Pay Lerii), 3. Gutta Pouteh (Boul Bal.), 1.
27 per cent.	Do.	Do.	1, 42	692	No. 22 is the typica material for telegraph-wir mixtures.
Much bark, 50 per cent.	Fairly hard but little nervy; cools fairly well	Do.	1, 05	900	A kind of Souni; th tested sample is a quit inferior quality.

No.	Name.	Geographical Origin.	Form.	Appearance.	Appearance when Cut.
25	Bolungan	East Borneo	Strongly formed pieces, clubs, having a hole on top which originates by falting the thinner part of the club on the thicker end when this is turned several times. Small loaves (the best) 4 to 11 lb., large ones up to 65 lb.	Blackish like soot, knotty like a club	White or violet-coloured, lets run out a sap which hardens at once in the fresh air on the knife; leaved
26	Do.	Do.	Do.	Do.	Do.
27	Do.	Do.	Do.	Do.	Do.
28	Do.	Do.	Do.	Do.	Do.
29	Do.	Do.	Do.	Do.	Do.
30	Coti	Do.	Pieces alike, rolls of about 30 inches long and 6 diameter; thin rolled leaves; the ends are turned over by hand, and show finger marks from kneading the gutta	Like covered by a net; the meshes are filled out with yellow or yellow-reddish pieces of wood; many pieces are marked, and are then nearly always somewhat reddish	Plainly leaved, white-yellowish or grey; separates a sticky fluid, like the Bolungan. The marked pieces have also a more reddish cut
31	Do.	Do.	Do.	Do.	Do.
32	Do.	Do.	Do.	Do.	Do.
33	Do.	Do.	Do.	Do.	Do.
34	Do.	Do.	Do.	Do.	Do.
35	Cotoman	(?)	Small, flat loaves or purls, 4 to 6 lb.	Surface very smooth	Very white; separates a sticky fluid

Nature and Quantity of Impurities.	Value.	Nature of the Thread.	Proportion of Gutta-percha and Resin.	Specific Resistance in Megohm-centimetres.	Notes.
Very clean, but adulterated, with large pieces of bark, about 5 to 20 and even 50 grammes, all of the same shape and kind, probably coming from the producing tree. They are so alike and regular that they must come from a plant growing near the gutta tree, but it is more than likely that they come from the same tree. 30 per cent.	Hard, nervy gutta, cools easily	Shrivelled thread	3, 54	302	The best of the kind for insulation; difficult in manufacturing.
30 ,,	Do.	Do.	1, 26	310	... ...
46 ,,	Do.	Do.	2, 47	208	... ...
45 ,,	Do.	Do.	3, 39	780	... ...
27 ,,	Do.	Do.	3, 03	30	... ...
Little bark, 30 per cent. The marked pieces contain more bark	Hard, fairly nervy, cools easily. The marked pieces are a better quality	Fairly smooth	1, 87	72	Somewhat like the Gutta Bolungan.
26 per cent.	Do.	Do.	1, 81	120	... ...
33 ,,	Do.	Do.	1, 54	43	... ...
33 ,,	Do.	Do.	1, 90	453	... ...
42 ,,	Do.	Do.	1, 20	829	... ...
No or little bark, but much water; 30 per cent.	Hard, but not nervy; cools easily	Very smooth	1, 56	3045	The separated fluid smells like foul cheese. Loss by washing, 30 per cent.; of these only 2 per cent. firm substances

No.	Name.	Geographical Origin.	Form.	Appearance.	Appearance when Cut.
36	Kelatan	North-east of Malacca Peninsula, North of Pahang	Balls about 1 to 2 lb., consisting of threads, analogous to African caoutchouc balls of threads	When fresh, pink and wax-like; later, chalk white	Very white; separates a sticky fluid
37	Do.	Do.	Do.	Do.	Do.
38	Do.	Do.	Do.	Do.	Do.
39	Pahang-White	Pahang	Balls of more than lead size	Chalk-white	Can be pulverised
40	Do.	Do.	Do.	Do.	Do.
41	Assahan	North-east of Sumatra	Do.	Do.	Do.
42	Tringanau	North-east of the Malayan Peninsula, on the bank of the Kelatan	Do.	Do.	Do.
43	Boula-Balam	Malacca	Ill-shaped pieces, pressed to blocks, as they otherwise pulverise	Do.	Do.
44	Gutta-Poutch	Sumatra	...	...	...

Nature and Quantity of Impurities.	Value.	Nature of the Thread.	Proportion of Gutta-percha and Resin.	Specific Resistance in Megohm-centimetres.	Notes.
30 per cent.	Easily pulverised; on the whole not very hard; cools not very easily	Very smooth	1	2101	Two kinds are known by this name; the one shows plainly that it is the same as gathered; this is the Gutta vierge (No. 36); the other consists of two parts, an inferior kernel, covered with a superior material. The quality becomes brittle after a little while.
40 " "	Do.	Do.	0, 95	743	... ...
33 " "	Do.	Do.	0, 98	1038	... ...
40 " "	Fairly nervy, sticky, cools easily	Very smooth thread, but difficult to work by itself, because it sticks to the cylinders	1, 15	860	The surface consists often of a layer of nervy gutta, only a few millimètres thick. Smells like fresh cheese.
19 " "	Do.	Do.	1, 16	743	... ...
20 " "	A little inferior to the above quality, more sticky, does not cool well	Do.	0, 90	743	The surface consists often of a layer of nervy gutta only a few millimètres thick. Smells like fresh cheese.
31 " "	Do.	Do.	1, 18	743	Do.
31 " "	Soft gutta without nerve; the pieces stick together even a few days after they have been cooled. Talc has to be used to prevent the forming of one mass	Cannot be used by itself for manufacturing purposes	0, 52	Cannot be fixed	The tree is not nearer described; grows in the marshy parts of the gutta countries. All gutta qualities are to a certain extent adulterated with this material. In spite of low price there is little demand, probably because there is sufficient contained in the white gutta, and the latter must be used for mixing to make this quality at all useful.
...	...	...	...	...	... ...

Léon Brasse did not hope to tabulate all the sorts on the market, he had to choose amongst the known commercial qualities before he could tabulate the mentioned types. The notes as to origin were supplied by well-informed importers and local Singapore traders. All sorts concerning which there are differences of opinion regarding value, although their physical and chemical character give a homogeneous whole, have not been taken into account. Other known sorts had also to be omitted because the varieties of the results did not permit of counting them as fixed types. Only one quality of this kind, called Sarapong or Soumi, has been taken as an example. The mention of the numerous irregular mixtures which come daily on the market has been avoided, and also the so-called "boiled up" substances of inferior quality which Chinese middlemen concoct on board ship or produce in some hidden corner or cellar.

It is impossible to purchase a quality of distinct origin from the importers; the material has to be taken as it comes, *i.e.*, as the traders in Singapore or Macassar compound it. Each firm marks its products with a brand of its own, and they are compounded according to their mechanical properties; every new supply brings surprises, and often of a disagreeable kind. This does not much matter if the material is for ordinary use, when a cheap price is of greater importance than quality and durability, but for electrical work, and especially for submarine cables, it is of the greatest importance.

It has been stated that nearly all gutta trees of Sumatra and the Malayan west coast are known, but that those of the Malacca east coast are still uncertain. The Sumatra gutta-percha has never been looked upon as first quality; the so-called Macassar qualities, which come really from Banjermassin, Kotaringin, Coti, Bolungan, and Sandakan, have always been ranged higher. Pahang has recently started exporting some gutta which surpasses in quality all other products, verifying the statement of Seligmann-Lui, but it is difficult to believe that the Pahang quality is, like the Borneo, a product of the Palaquium genus.

The latex of the Palaquium thickens directly it leaves the tree, making it impossible to collect it without parts of bark; all explorers are unanimous on this point. The gutta-percha is therefore always coloured by substances contained in the bark, which can be noticed when the material is cleaned and boiled. But the Pahang gutta-percha is a whitish-yellow, and contains

only a few impurities. Two conclusions can be drawn from this, either the latex runs plentifully, and does not coagulate directly, as with the *Payena Lerii*, and the trees in Soupayang and Halaban, or the gutta-percha is very clean, and as it does not absorb the colouring material of the bark it must be another kind. Nothing is yet known about the Pahang trees, and their supply and collecting methods are still obscure. Leys' report about the Borneo gutta-percha is quite contrary, regarding colour and supply, to all other Palaquium results. It is, therefore, more than likely that the gutta tree of North Borneo is not a Palaquium. The Sandakan gutta is like the Pahang; it is very clean and whitish-yellow. Sarawak is more reddish, and shows a large and seemingly wilful adulteration with bark; white veins can always be found, but they show few foreign substances.

Not much can be said about the qualities coming from Pontianak. It has been stated that the territory contains Palaquias.

A comparison between the related Kotaringin and Banjermassin sorts is interesting. Kotaringin is a very clean and often quite white gutta-percha, whereas Banjermassin contains much bark, and is always strongly coloured. If these pieces of bark came from the collection, and if these gutta-perchas had to be manipulated for cleaning as described for the Palaquias, the Kotaringin would be the best washed and most natural coloured quality of the two. But this is not so. It is more than likely that the Banjermassin impurities are added after the felling of the trees to mislead any inquirers, and to retain the evidently well paying monopoly.

The same can be said of the very white and pure Maragulai gutta-percha. The Bagan and Pegan gutta-perchas have different properties distinguishing them from the Palaquias; they are more like the balata of the Mimusops-Balata, and the Bagan gutta-percha suggests especially not a coagulation but a vaporisation of the latex, as used in Guiana, or by the Sumatra method.

The Sumatra gutta-perchas are products of the *Palaquium oblongifolium*, more or less mixed with the *Payena Lerii;* the Bouha-balam are products of less-known gutta plants. The Palang gutta-percha has all characteristic signs given by the explorers to the Palaquias, red colouring, bark, etc., etc. Souni is only an unknown mixture in different proportions.

The botanical origin of the Bolungan and Coti genus can only be fixed with difficulty. Were it not for the specific

resistance the same could be said as for the other Borneo gutta-perchas, but the specific resistance is much higher, and increases with every collection. Nos. 29, 30, and 32 of the tables are qualities which have been collected during ten years, the others are younger. This has been brought about by the failure of the Sandakan, now the natives have to make different mixtures. The higher specific resistance is probably caused by the latex of the *Payena Lerii*. This tree supplies such a latex as can be seen out of Nos. 35 and 36 of the tables, but the latex easily forms resins, giving a higher resistance, but making the gutta-percha brittle (see Nos. 37 and 38). Here is the reason to be found for the rejection of the exclusive use of gutta-percha for the higher insulation in cable production. Small quantities are used, but the desire for easier working must not transgress the limits of the calculation, otherwise faults can arise which will be noticed too late, and many of the drawbacks only show after the manufacturer has ceased to be responsible for his production.

The qualities coming from Assahan and Trenganu, also the white Pahang gutta, are undoubtedly a mixture of Payena and Bouha-balam latex. All the white gutta-perchas have a smaller specific resistance than the products of the Payena latex, and this is probably the reason why the very resinous Bouha-balam latex is added, but nothing definite can be stated, as the specific resistance of the Bouha-balam has not yet been fixed.

Léon Brasse's opinions may be summed up thus :—

(1) All superior sorts of gutta-percha have a small specific resistance, and it is by no means proved that they are the product of Palaquias.

(2) The Gutta-Pahang, the product of the *Pal. obl.*, is a gutta of medium quality, and its specific resistance is very high.

(3) The qualities Bolungan and Coti, which were formerly used, have small resistance, which now increases more and more, and care has to be taken when they are used.

(4) All white sorts have a high resistance, they cannot be used for manufacturing cables, not even when mixed with small quantities of other products.

(5) It cannot be asserted that only gutta-percha of the Palaquium tree was used for the first submarine cables. Its specific resistance is about 400,106 Megohms, but there is no cable known in England which has a resistance over 120,106.

(6) The best sorts of gutta-percha are Pahang, Sarawak, and Sandakan.

The most prominent and nearly exclusive trading centre for the export of raw gutta-percha from the Malayan Archipelago is Singapore, and here the Chinese have nearly the whole of the trade. All the supplies from the islands, and also the smaller quantities from Bengal, Burmah, Cochin-China, Japan, and even Arabia, centre here to find their way to the industrial markets. It is noteworthy that the export largely exceeds the import into Singapore, and the explanation of this can only be the manipulations or adulterations by the Chinese merchants. According to O. Collet ("Etudes sur la Gutta-percha," 1902, Bruxelles), they are rightly or wrongly accused of manufacturing in the shops any quality or quantity to order, not shrinking from the most shameless deception. The import and export to Singapore gives a picture of the total raw gutta-percha production. According to the Straits Settlements Government's Gazette, bluebooks, and statistical reports, E. Obach calculated the quantity of imported gutta-percha at Singapore for the period 1885-96 at 542,081 cwts., valued at £3,547,787, giving an average price of 1s. 2d. per lb. The attached table groups the value in four different divisions, which give an idea of the production of the different kinds and their average value, which varies between 12.9 and 17.5 pence per lb.

Import of Raw Gutta-percha in Singapore (Quantity and Value) from 1885 to 1896 Inclusive.

Origin.	1885.		1886.		1887.		1888.		1889.		1890.	
	Cwts.	£	Cwts.	£	Cwts.	£	Cwts.	£	Cwts.	£	Cwts.	£
Malayan Peninsula	8,503	22,354	2,897	16,926	1,352	8,418	1,026	5,378	1,938	15,429	982	8,275
Borneo, Sulu Islands, Labuan, Celebes, Natoena Islands	3,650	26,707	4,508	28,291	3,186	19,981	2,950	21,928	4,251	29,391	2,231	16,044
Sumatra, Java, Bali, etc.	47,126	207,365	33,737	216,350	30,090	212,924	34,083	274,869	74,789	384,379	21,323	150,480
Arabia, Bengal, British Burmah, Siam, Japan, Cochin-China, etc.	12	71	48	331	...	...	...	...	97	375	39	200
Total	54,291	256,497	41,190	261,898	34,578	244,353	38,059	302,175	81,075	429,574	24,575	174,999

Import of Raw Gutta-percha in Singapore—*Continued.*

Origin.	1891.		1892.		1893.		1894.		1895.		1896.		Total.		Average per Lb.
	Cwts.	£	Cwts.	£	Cwts.	£	Cwts.	£	Cwts.	£	Cwts.	£	Cwts.	£	
Malayan Peninsula	3,148	29,358	4,981	59,058	3,095	24,024	3,147	25,090	3,508	27,070	4,760	38,124	34,332	280,434	17,5
Borneo, Sulu Islands, Labuan, Celebes, Natoena Islands	19,011	178,871	20,06[illegible]	156,907	21,944	144,442	20,239	147,031	17,632	123,978	17,711	147,978	137,329	1,041,549	16,8
Sumatra, Java, Bali, etc.	30,976	222,912	19,554	155,130	20,247	103,921	23,630	109,682	15,971	91,472	18,502	93,927	370,028	2,223,411	12,9
Arabia, Bengal, British Burmah, Siam, Japan, Cochin-China, etc.	84	941	...	...	8	26	66	177	31	210	7	62	392	2,[illegible]3	13,1
Total	53,214	432,082	44,601	371,095	45,294	272,413	47,082	281,980	37,142	243,630	40,980	280,091	542,081	3,547,787	14,0

The total export of raw gutta-percha for the same time, 1885-1896 (including both these years), from Singapore amounted to 619,377 cwts. of a total value of £4,855,791, an excess of 77,296 cwt. and £1,308,007 over the import. These explanations are offered for this remarkable phenomena: large surplus quantity left in stock before the period 1885, unreliability of the statistical record, and the already mentioned manipulation and adulteration by the merchants; probably the three reasons combined account for the extraordinary result. The countries absorbing the given quantity of raw material coming from Singapore (the figures are those for 1885-96) range as follows:—

Great Britain	470,770 cwts.
France	54,215 ,,
Germany	47,151 ,,
United States	37,894 ,,
Asia	4,241 ,,
Holland	4,202 ,,
Italy	895 ,,

Two-thirds of the total export of Singapore went to England, and England re-exported.

1885	1886	1887	1888	1889	1890	
9,666	11,528	8,824	8,373	8,304	11,456	cwts.
1891	**1892**	**1893**	**1894**	**1895**	**1896**	
6,408	7,989	7,430	9,975	12,536	14,497	cwts.,

a total of 116,986 cwts., leaving not quite three-fourths of the import for home-production and stock. The English re-export in 1885-96 found its way to :—

Germany	about	48,100	cwts.
France	,,	26,000	,,
Holland	,,	16,400	,,
United States	,,	11,500	,,
Other countries	,,	11,300	,,
English colonies	,,	3,700	,,

The import and export of a raw gutta-percha for the years 1897-1900, according to a publication of the English Colonial Office, were as follows :—

IMPORT OF RAW GUTTA PERCHA IN SINGAPORE.

Season : April—March.	1897-98.		1898-99.		1899-1900.		1900-1901.		1901-1902.	
	piculs.	cwts.	piculs.	cwts.	piculs.	cwts.	piculs.	cwts.	piculs.	cwts.
ORIGIN :										
Malacca and Penang - - -	2,839	3,371	3,169	3,761	3,815	4,531				
British North Borneo - -	990	1,176	1,127	1,338	967	1,148				
Labuan - -	240	285	423	503	680	808				
Dutch possessions	27,239	32,346	49,592	58,890	51,906	61,638				
Malay Peninsula -	1,991	2,365	1,790	2,126	1,950	2,316				
Sarawak - -	2,235	2,654	3,672	4,361	5,132	6,095				
Other countries -	19	23	84	100	139	165				
	35,553		59,857		64,589					

EXPORT OF RAW GUTTA-PERCHA FROM SINGAPORE.

Season : April—March.	1897-98.		1898-99.		1899-1900.		1900-1901.		1901-1902.	
	piculs.	cwts.	piculs.	cwts.	piculs.	cwts.	piculs.	cwts.	piculs.	cwts.
DESTINATION :										
United Kingdom -	28,230	33,523	51,154	60,745	61,975	73,595				
Penang - -	333	395	321	385	266	316				
Germany - -	10,099	11,993	16,997	20,183	8,140	9,668				
France - - -	5,339	6,340	5,830	6,923	6,983	8,293				
Italy - - -	74	88	297	353	134	159				
United States -	1,134	1,347	18,448	21,907	535	636				
Belgium - -					121	144				
Other countries -	208	247	348	413	189	224				
	45,417		93,398		78,343					

N.B.—A picul = 133 lb.

These tables show the same misproportions in the important export of Singapore as those quoted for the years 1885-96, and this must certainly be considered as very remarkable.

The statistics published by the London Chamber of Commerce give the total import of raw gutta-percha, including balata, for the years

	1897	1898	1899	1900	1901	
as	41,442	63,238	82,497	126,059	83,438	cwts.,

whereas the exports, also including balata, amounted for the same years to

7,674	10,278	7,502	15,266	10,936	cwts.

The re-export was distributed over

Russia .	329	101	286	82	8	cwts.
Germany .	2,306	4,215	2,130	6,750	3,553	,,
Holland .	2,038	3,236	708	3,698	3,439	,,
Belgium .	120	436	426	377	247	,,
France .	1,938	1,242	707	1,935	1,157	,,
United States	675	910	3,067	2,014	1,644	,,
Other countries	268	138	176	410	894	,,

Besides Liverpool and London the principal markets for gutta-percha in Europe are Marseilles, Rotterdam, and Hamburg. Rotterdam and the whole Netherlands have permitted the English markets totally to absorb the Dutch colonial gutta-percha trade, whereas Hamburg becomes more and more a direct importer. It is a pity that the statistical office at Hamburg does not differentiate between gutta-percha and balata, they are thrown together, and separate figures are therefore not obtainable.

Hamburg's total import of gutta-percha (and balata) is recorded as

1899	1900	1901	
17,957	20,656	16,697	d.z.

one d.z. = 100 kilos = 2 cwts.

The clear view of variations in price on the international gutta-percha market, possible in the case of caoutchouc, cannot

be given, because gutta-percha has not the necessary definitions for qualities to permit a distinct recognition of each kind. To this must be added the change in quality of the different kinds; some have disappeared, others have come fresh on the market, and several qualities are now called by quite different names.

The gutta-percha market is not exposed to such strong and sudden changes in price as the caoutchouc market; the prices change only rarely and it is seldom that a great variance has to be recorded. Each species has generally a scale of three prices, according to the quality, which are called first, medium, and lower quality. According to the species the prices vary from about 5 dollars per picul, as for instance for Gutta Djiloetong (Dead Borneo), up to 450 dollars for Bila 1. rouge, and 600 dollars for fine Pahang red. To fix an average is impossible.

V.—Chemical and Physical Properties of Gutta-percha.

THE difference in origin and the rare occurrence of pure unadulterated material produced from one and the same kind of plant makes it impossible clearly to fix the physical and chemical properties of gutta-percha in all cases. The following observations are based on tests of the better-class sorts and can on the whole be taken as correct.

Pure gutta-percha is colourless, and when finely cut, transparent. A sheet about $\frac{1}{5}$-millimètre thick laid on a white object has a specific colouring between pink and greyish white. It is tasteless and inodorous, and if it smells it is on account of decomposition. The material has a cellular structure, but when firmly stretched it becomes fibrous and is very strong in the direction of the pull, at the same time losing strength in the other direction, and breaking when put to a strain on this point. Single pieces are not adhesive under ordinary temperatures, but when heated on the surface and pressed together they adhere together, and the pieces cannot be detached without injury. Under ordinary temperature it is thick, smooth, very tough, and little elastic: the better qualities resist a tearing-strain of about 24 kilos per square millimètre when stretched 50 to 60 per cent.; it can be folded, pulled, tied in a knot, and as easily cut to pieces by sharp-edged and pointed tools. The elasticity is the same as that of soft leather. Gutta-percha is impermeable, but has a certain porousness; placed in water it absorbs it, but only in the cells on the surface.

The specific weight is as a rule 0.979 to 0.999, but in reality it is heavier than water. Strongly pressed pieces do not float, their specific weight is about 1.010 to 1.020.

At a temperature of 99° F. gutta-percha becomes soft; at 122° it follows the slightest pressure, at 195° it becomes plastic and can be kneaded and moulded into any shape, which it retains under usual temperatures. At 265° the material melts, and if heated to a higher degree it bubbles and distils a colour-

less oil. Brought into contact with a flame it ignites quickly and burns with a shower of sparks, leaving a blackish residuum.

Cold does not affect gutta-percha much: at several degrees below zero no changes are noticeable. The same can be observed by contact with cold water, of which it absorbs a little in the surface pores. Like vulcanised caoutchouc, gutta-percha is preserved best in cold water, and both are equally affected by atmospheric air and light, which seem to cause an oxidation. When moistened gutta-percha is exposed to the sun's rays, it becomes brittle, pliable, loses in electric resistance, and becomes at last itself an electric conductor. Clark and W. A. Miller have made interesting experiments on the influence of air and light. Equal quantities of the same material were kept for eight months under the following conditions:—

(1). In air and light, protected from water.
(2). In air, protected from light.
(3). In pure water, with access of air and light.
(4). ,, ,, ,, protected from light.
(5). ,, protected from air and light.
(6). In sea water, with access of air and light.
(7). ,, ,, ,, protected from light.
(8). ,, protected from air and light.

The samples, 3, 4, 5, 6, 7, and 8, showed no changes beyond a slight addition of weight caused by the filtration in water. Sample 1, which had been rolled and placed in an upturned bottle, had added 5 per cent. oxygen, and 55 per cent. of the mass exposed to light was resinous and brittle, whereas the parts not exposed to light had hardly changed in structure or appearance. Sample 2 had undergone little change, it had added ½ per cent. to its weight, and when treated with alcohol showed 7.4 per cent. resinous contents. A similar test, exposing a sample of gutta-percha for two months to the light, had another result; the material had added 3.6 per cent. to its weight, was brittle, and showed 21.5 per cent. resinous contents when treated with alcohol, whereas a piece of the same kind kept in the dark showed no noticeable changes. This proves that the influences of air and light are not always the same and depend more or less on the qualitative properties of the gutta-percha. To prevent the disastrous influences of oxidation 10 to 12 per cent. of wax or tallow is added, but the best protection against oxidation is to keep the gutta-percha in water.

Gutta-percha is a bad conductor of heat, and even a worse one of electricity; when strongly rubbed it becomes electric, and when rubbed with silk it gives electric sparks. In its resistance to the electric current it is unapproached by any other known plastic material, and it retains these properties in the earth as well as under water; it is an insulator *par excellence.* Wunschendorff states the electric resistance of gutta-percha at a temperature of 75° F., copper taken as a unit as 6×10^{19} = 60,000,000,000,000,000,000. This cannot be said of all sorts which come on the market, and the exact standard of electric resistance and the electrostatic capacity varies in each sort. As an expression of electric resistance of a circular cylinder, the formula

$$R = \frac{A \log \frac{D}{d}}{L}$$

is applied, in which R is the resistance, A the specific insulation constant, D the external, and d the internal diameter, and L the length of the cylinder. The specific electrostatic capacity of the gutta-percha, the air as a unit, is 4.2. As formula for the capacity of a circular conductor of gutta-percha.

$$C = \frac{A\ L}{\log \text{nat} \frac{D}{d}}$$

is applied. C is the electrostatic capacity, A the specific induction capacity of the gutta-percha, L the length, and D d the external and internal diameter of the cylinder. The honour of having fixed the enormous resistance of gutta-percha to electricity belongs to the English physicist Faraday, who discovered it in 1843.

Gutta-percha is insoluble to most reagents. In cold water it cannot be dissolved, and when it is softened in boiling water or steam, it does not change at all. In impure cold alcohol it does not dissolve, but the purer the alcohol the greater the solvency, increasing with the temperature, and in boiling pure alcohol it loses 15 to 20 per cent. of its constituents. It is partly soluble in oil of turpentine, olive oil, and a few mineral oils, but still more in benzin. The best solvents for it are bisulphide of carbon and chloroform. Gutta-percha resists corrodent alka-

lies, ammonia, and unoxidising mineral acids; concentrated hydrochloric acid has no effect, but concentrated sulphuric and nitric acids, also free chlorine, affect it very strongly.

Gutta-percha as put on the market is not suitable for chemical tests, a preparatory treatment is needed before analysis. Payen dissolved ordinary gutta-percha in sulphuric acid, filtered it, let it evaporate on a marble or glass basis in the open air, and then cooled it in water.

Miller states that 100 parts of ordinary commercial gutta thus treated give

Pure gutta-percha . .	79.70
Resins	15.10
Vegetable fibre . .	2.18
Water	2.50
Ash	0.52
	100.00

The extracted resins were grouped in six variations according to their solvency in ether and alcohols. The pure gutta-percha prepared after Payen's recipe showed

Gutta . .	78—82 per cent.
Albane . .	16—14 ,,
Fluavile . .	6—4 ,,
	100

Fluavile is a transparent yellowish resin, a little heavier than water, and soluble in cold alcohol; it is hard and becomes brittle at freezing-point; at 122° F. it becomes soft, at 140° plastic, and at 210° to 230° quite fluid. According to Oudemans it is a compound of

	I.	II.
Carbon .	83.36	83.52
Hydrogen .	11.17	11.42
Oxygen .	5.47	5.06
	100.00	100.00

and has the formula $C_{20}H_{32}O$.

Albane is a white crystalline resin, heavier than water, and becoming fluid at a temperature of 320° F., it is impervious to hydrochloric acid, and is soluble in benzin, oil of turpentine,

bisulphide of carbon, ether, and boiling alcohol. According to Oudemans it is a compound of

Carbon .	I.	78.87	II.	78.95
Hydrogen .		10.58		10.31
Oxygen .		10.55		10.74
		100.00		100.00

and has the formula $C_{20}H_{32}O$.

Gutta, the main element of gutta-percha, is impervious, smooth, between 50° and 85° F. not elastic, but softens at 114°, when it colours brown, and becomes, with the rise of temperature, more or less sticky, and gives, on distillation, a hydrocarbon which is not unlike caoutchouc. Towards acids, diluted alcohol, ether, and chloroform, it acts like gutta-percha. Oudemans states its compounds as

Carbon .	I.	87.64	II.	88.10	III.	83.20
Hydrogen .		11.79		11.77		12.00,
Oxygen .		0.57		0.13		
		100.00		100.00		

which gives the formula $C_{20}H_{32}$ or C_5H_8.

In closing this chapter the animal enemies of gutta-percha must be mentioned as they very often destroy gutta-percha insulated electric lines. In the sea it is the *Teredo navalis*, a worm about twelve inches long, and also the *Limnorium Lignorum* or *Tenebrans*, a crustaceous animal of the size of an ant. The latter are dangerous, owing to their small size, which permits them to enter the smallest holes. Land cables are often attacked by rats, and the *Templetonia crystallina*, a microscopic small insect of the Podura family. The enemies in the sea can only be guarded against by a metal armature, and on land the embedding of the cable in cement is necessary.

VI.—Manufacture and Application of Gutta-percha.

BEFORE the raw gutta-percha can be used for manufacturing purposes it has, like caoutchouc, to undergo several preparatory treatments, to make it suitable, and to remove foreign substances, such as sand, earth, wood, bark, and other impurities. Several simple methods are adopted. The raw pieces, loaves, or blocks, are first cut into slices on the cutting machine, and come then on a drum spiked with knives, to continue the chopping process. The triturated material is plunged into cold water to remove the heavy compound from the floating gutta-percha, before it comes into tubs with hot water, where it remains until it is soft, when the chopped pieces become again one plastic substance.

Gutta-percha not requiring the highest qualities and properties for electric use can now at once be produced, and many are the articles for technical and other purposes which are made of it. But if the material has to be used for the finest electrical work, all traces of water and air-bubbles have to be removed, and this applies especially to gutta-percha for insulating, which must be an absolutely homogeneous mass. To attain the needed perfection the material has to undergo several other processes.

It is put next into the real washing-machine, which consists of an outer iron case, which has in the interior a hollow cylinder with another iron shaft with four, five, or six winds. The outer case can be closed by a cover. The inner cylinder has also a cover through which the gutta-percha enters. Case and cylinder are filled with water, heated by a direct supply of steam. As soon as the inner shaft is set in rotation by a transmission gear, the gutta-percha is forced between the walls of the cylinder and the wings, and to increase the effect two noselike rails are fitted on the bottom of the cylinder, thus narrowing the space through which the material has to pass. The washed out impurities of the gutta-percha fall on the bottom of the cylinder, and through small holes in the outer case, where they settle down and are removed from time to time (Fig. 25).

Out of the washing-mill the gutta-percha comes into the dry kneading-mill (Fig. 26), which is similar to the washing-mill, with the exception of the outer case. In the interior it has a fluted shaft, and the grooves run either along the axle of the shaft, or, with more or less variation, they run in a spiral line. The kneading is the same as the washing, excepting the water; the needed temperature is introduced by steam, which plays between the double walls of the cylinder. Some kneading-mills have two horizontal shafts side by side, which work together, and for these constructions a fluted and a smooth, or two equal shafts with slanting elliptic rings are chosen. The shafts of the latter kneading-mills are so fitted in that the discs or rings must cross when running.

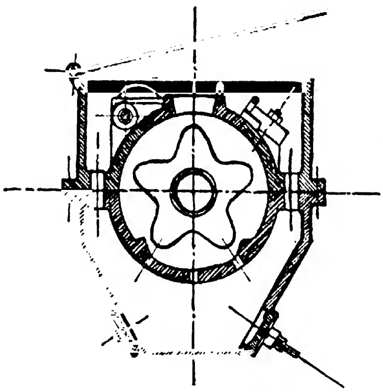


FIG. 25.

From the kneading-mill the gutta-percha comes very often in a press (a strainer), consisting of a cylinder which has at its lower end several sieves on top of one another, each with different sized meshes or perforated bottoms. The meshes of the sieves or the perforations of the bottoms get smaller the lower they stand, and the top ones are very wide; the very last one can have a bottom with any perforation. An exact fitting movable die forces the soft gutta-percha through these holes. The strainers (which are in construction not unlike the hydraulic presses for vermicelli production) are sometimes supplanted by filter presses. The gutta-percha is so thoroughly worked in these presses that all the retained air and water are removed, and the material is one homogeneous whole. To permit of more convenient storage and handling of the whole material until it is used for manufacturing, it passes a set of shafts where it is cut in thick and thin sheets. These rolling-mills consist of two vertical or slanting rollers, one on top of another; they have very smooth surfaces, and are similar to the calenders used for the production of caoutchouc. The material is placed between the rollers in front of the mill; when

the sheets leave they are taken on by an endless cloth and transported away.

The future product requires in most cases a special density, elastic or other electric properties, which are only seldom found to the needed extent in a quality of raw gutta-percha, and the manufacturer has therefore often to mix several kinds. Only practical study and experience have led to good results, and, just as with caoutchouc, the production remains a close secret.

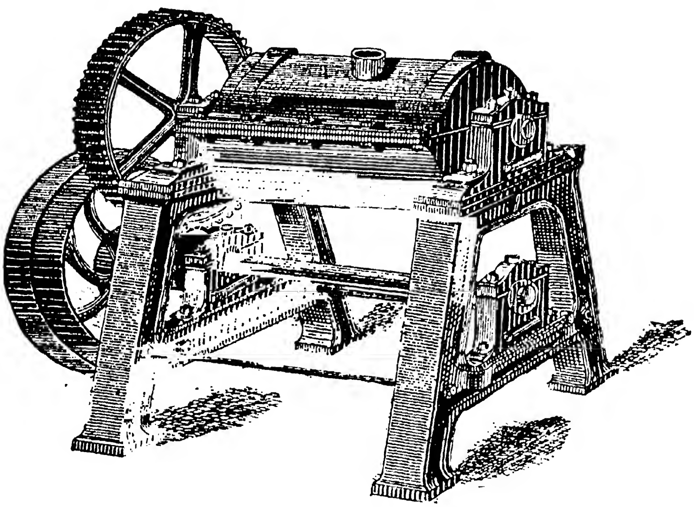


FIG. 26.

The mixing of gutta-percha with other materials, as described in the case of caoutchouc, is rare, and manufacturers desiring good qualities do not think of it, as it always means a lowering of the quality, which cannot be justified by a reduction in price. The same apparatus are used for mixing as for kneading.

Like caoutchouc, so also gutta-percha suffers from washing and kneading, and shows a not inconsiderable reduction of the original weight, which differs according to origin, quality, and other properties. The better quality loses, as a rule, 15 to 20 per cent., medium qualities 20 to 25 per cent., and inferior sorts suffer sometimes a reduction up to 50 per cent.

The further operations for producing the many required goods are the same for gutta-percha as for unvulcanised, mixed,

and rolled caoutchouc sheets. On the whole the manufacturing process is more simple than for caoutchouc, because gutta-percha is more plastic, can be more easily moulded, the seams can be joined without difficulty, and the difficult vulcanisation plays no part in the production.

Gutta-percha is in many cases a good substitute for leather, and is sometimes to be preferred. It is most useful in moist, damp, cold places, or for acids. It is used for tubes and pipes, for cold water, beer, vinegar, wine, and acid conduits; for driving-belts which have to run in the damp; for pails, ladles, bottles, syphons, and funnels in chemical factories; also for

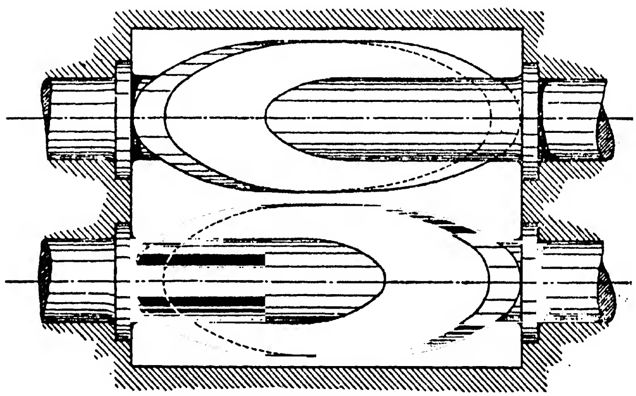


FIG. 27.

studs and rings for pumps and hydraulic presses; for washing-drums; for spinning-rolls; for roller covers in cotton mills; for photographic purposes, cases, and diving rods, and to make galvano-plastic moulds and matrices. For surgical purposes it is serviceable, and pure gutta is used for filling hollow teeth and for making new ones; when rolled as thin as paper many surgical bandages are made of it. As thin taffeta it is found inside hats and caps to prevent grease or perspiration going through; and is also used for dress-preservers and so-called flower-paper for the production of artificial flowers. Men's garments are often joined by means of it (in North America) instead of sewing them. An important application is its use for covering fulminating fuses for blasting, by means of which these can be laid through water without becoming useless. The most important application of gutta-percha is as insulating

material for electric conduction, especially submarine cables and those which have to be laid in the soil. For cable production it is quite an indispensable material, and some great practical results of the electric industry must be credited to gutta-percha, which supplies so many of its requirements.

The cuttings and the old material which the consumers return after use are of much greater value than those of caoutchouc; they are fairly pure, not mixed with foreign substances, and not vulcanised. The scraps left in manufacturing can at once be used again. The value of old material depends on the degree of oxidation and the chemical influences which certain acids and high temperature have had on the material. Old material of the latter kind is often nearly useless, whereas, if it is only oxidised, it can be treated with a hot solution of caustic soda, with benzin or turpentine, or by washing, kneading, and mixing with fresh virgin material, making it a part of a new substance.

The vulcanisation of gutta-percha can only be mentioned for its historical interest. As already stated in the introduction, the material has been treated with sulphur, and by the same methods as applied to the vulcanisation of caoutchouc. Total failure was the result; the good and characteristic properties of the gutta-percha were destroyed by the process without giving it advantages in any other directions. The vulcanisation of gutta-percha has, therefore, been entirely abandoned.

Balata.

Just as gutta-percha was at first taken for caoutchouc, so balata was looked upon as gutta-percha. The possibility of mistaken identity was in this case much easier, as the characteristic differences of balata and gutta-percha are not so marked as those of gutta-percha and caoutchouc. But the differences exist, and since the beginning of the 'eighties it has been insisted on that the material is different from the other two.

Balata is first mentioned in a published report to the Society of Arts in 1857 by Professor Bleekrode. He describes balata as Surinam gutta-percha, and drew the conclusion that the material was identical with the Isonandra gutta. The Colonial Secretary of British Guiana sent a sample of balata collected by Van Holst at Berbice to the secretary of the above-mentioned society, which was later on sent to the Kew Museum. The Society received further samples in 1864 from Sir William Holmes in reply to an offer for the best gutta-percha substitute. Holmes mentioned in his letter that he was a British Guiana Commissioner at the International Exhibition in 1862, where he exhibited ½ lb. of balata, which was given to Charles Hancock, who spoke very highly of it. This sample found, later on, its way to Kew also, where other samples from James Collins from British Guiana (1868), Governor Longdon, of Trinidad (1874), Im Thurn, of Demerara (1882), and G. S. Jenman (1884) are preserved; the last mentioned sent also balata milk, and balata samples produced with the help of spirits of wine.

The balata is, like the gutta-percha, the dried milky sap of plants of the Sapotacea family, exclusively belonging to the Mimusops genus, which can be found in all parts of the globe. But Mimusops supplying balata have been found only in the Antilles and Bahamas, Venezuela, British, Dutch, and French Guiana, and some parts of Brazil; on the west coast of the equatorial territory in Africa, Abyssinia, Angola, Madagascar, and the Mauritius Isles; in Australia, in Queensland, and also in New Zealand, and all known export has hitherto only taken place from one of these places.

The *Mimusops balata* (Gaertner) seems to be the same as

Mimusops balata (Blume), the *Achras balata* (Oublet), the *Lucuma mamosa* (De Vriese), and the *Sapota Muelleri* (Blume). The leaves are glossy, oval, and pointed, petiolate,

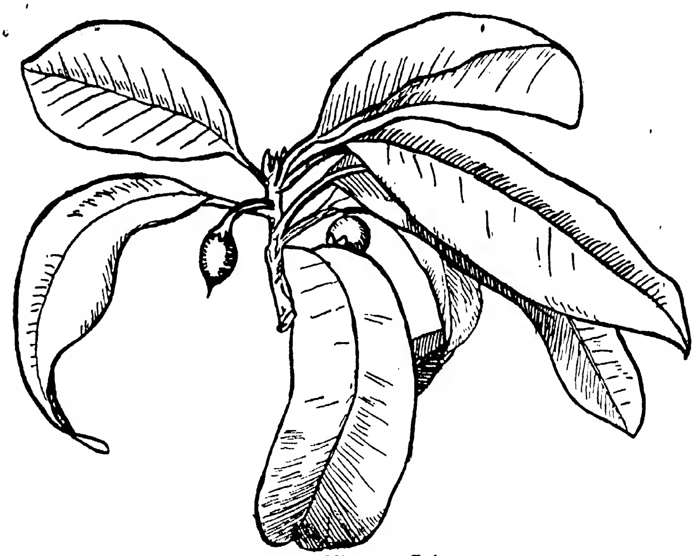


FIG. 28.—Mimusops-Balata.

4 to 6 inches long, and 2 to 2¾ inches wide; they are alternate on the ends of the branches. The illustration of the balata branch with fruit is taken from Professor Bleekrode's report

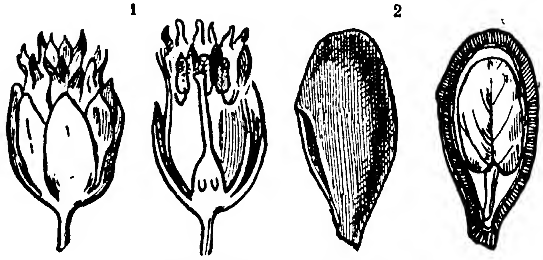


FIG. 29.—Mimusops-Balata.
1. Blossoms. 2. Seeds.

published in 1857. The flower has six parts, the corolla is white and about half an inch in size. The fruit is round or oval, palatable, and tastes like a plum. The latex of the tree diluted with water is used as a drink by the natives. The *Mimusops balata* grows on sandy or clay banks only a few feet

Tabulated Synopsis of Balata-supplying Plants of the Sapotacea Family.

Family.	Genus.	Variety.	Scientific Synonyms.	Local Names.	Botanist & Explorer.	Origin.
Sapotaceæ	Mimusops	M. balata	Achras balata, Lucuma mamosa, Sapota Muelleri, Iliguerona Mastota	Bullet-tree or Bolletrie, Manly-kara, Genuine or milking balata, red balata, Galibis balata, Muirapiranga	Aublet, Blume, Gaertner, D'Martin, De Vriese, Schomburgk, Boilley, Santa Anna de Nery	French, English, and Dutch Guiana (Monts Canukut, Barama, Surinam), Barbadoes, Antilles, Brazil (Amazon), Costa Rica
Do.	Do.	M. globosa	Do.	Purvio, Purgua, Mbear-ata (a hard thing)	Gaertner, Rousseau	Venezuela (prov. Maturin)
Do.	Do.	M. electa	Do.	Macaranduba, Apraiù	Bernardin da Silva, Cantinho	Brazil, Venezuela (Suirido and Guaviare)
Do.	Do.	Species	Do.	Maparauba	Do.	Brazil
Do.	Do.	Do.	Lucuma gigantea. ,, fissilis, ,, lastiocarpa, ,, laurifolia, ,, procera	Iaquá, Garaquá, Abiarana, Guapeba vermelha, Chana, Macaranduba blanca	Do.	Do.
Do.	Do.	M. speciosa, M. Schimperi, M. Kuemmel	Abyssinian Mimusops	Cafequesu, M. Bimo	Do.	Angola, Gabun, Abyssinia
Do.	Chrysophyllum	Chrys. ramiflorum, Chrys. species	Do.	Baca, Guaraita, Leitero de Mato	Do.	Brazil, Niger
Do.	Do.	Achras Australis, Sano Manilla, Imbricaria coriacea	Do.	Do.	Do.	Queensland, New South Wales, Madagascar, Mauritius Isles

over the level of marshy swamps. They are found in Jamaica, Trinidad, Venezuela, British, Dutch, and French Guiana, and some say also on the Amazon River. They are widely distributed over the alluvial lowlands of British and Dutch Guiana, between the banks of the Berbice and the Corentyne. Large numbers of trees are to be found here, but collecting is difficult owing to the density of the forest, in which the trees can only be reached by boat. The trees grow slowly, they reach a height of 120 feet, and have a wide branching crown. The cylindrical stem is 60 to 70 feet high by a diameter of 4 to 5 feet; it has hard wood, weighs about 88 lb. per cubic foot, and is used for buildings and mill rollers. Owing to its red colour the wood has, in the Dutch colonies, the name of "paardenflesch" (horseflesh).

Besides the *Mimusops balata*, the following other Mimusops trees supply balata:—*M. electa*, *M. globosa*, *M. speciosa*, *M. Schimperi*, *M. Kümmel;* also the Lucumus trees *L. gigantea*, *L. fissilis*, *L. lasciocarpa*, *L. laurifolio*, *L. procera*, and a few trees of the Crysophylla genus.

The table gives all the plants belonging to the Sapotacea family and supplying balata, their scientific and local names; their origin and the names of botanists and explorers who have dealt with the plants are also given.

To collect the balata latex it is not sufficient to make a few cuts in the bark as with caoutchouc plants, the latex of the Mimusops is so thick and coagulates so quickly that every incision would soon be stopped up. The Venezuelan collectors cut, therefore, the stems off at the root, lift these on rests, and let the latex run out of the foot-wide incisions into pails. By means of this barbarous method, about three to six kilogrammes of balata were obtained from a medium-sized tree. To-day, hand presses are used which submit the bark to a strong pressure. One press supplies nine to thirteen litres of latex per hour, equalling about two to three kilos dry balata. In a district including the Venezuelan provinces Cumana, Barcelona, and Isle Margarita, very large trees are found which give several hundredweights of balata by the last-mentioned method. This system of destruction is very lucrative and has spread far and wide; if it is continued the Manturiñ district will, in spite of its great natural resources, soon be exhausted.

In Dutch Guiana, especially in Surinam, the trees are tapped and the bark is cut up to a height of twenty feet. The incisions are connected, and the latex runs from one groove to the

other until it reaches the lowest, where it is collected (like caoutchouc) in a calabash or gourd bottle, and comes afterwards in a tank with a handle called "goobe." The latex is either sold as such in the goobes or it is poured into wooden evaporation plates in which the water evaporates, leaving a ¼-inch skin on top, which is taken off and dried on a line. The drying takes several weeks, as the balata skin is hard and retards evaporation. A gallon of latex gives 4 lb. dry balata. A fairly clever workman collects 4, and an expert about 10 gallons per day. In Dutch Guiana the collection is regulated, and the collector has to pay the Government five cents per hectare for a permit. Most collectors hire a district of about 200 hectares and more. The natives from the British colonies are hired, and they are bound to supply their whole harvest for a certain price to the employer. The collectors work generally in groups of three or four, find their own board and lodging, and the contractor only sends them in canoes to the collecting places. As a rule the stems are tapped one year on one, and the next year on the other side, and by careful handling the tapping can be repeated a few years later. The results depend much on the weather; when it is very dry the boats cannot easily cross the many rapids. The undertaking is as a whole a risky one, and bad weather is unfavourable to contractor and collector. The forest climate is very unhealthy for all Europeans, the forests are generally very dense, letting in no sunrays, the drinking water is full of vegetable impurities, and fever and rheumatism are prevalent amongst the collectors.

The collecting method in British Guiana is the most rational. The stem receives several longitudinal incisions, between which the bark is taken off, but the liber remains, and soon a new bark is formed. It is best to remove the bark in alternate rectangular pieces. The removed bark is pressed, and a medium-sized tree supplies by this method about 2 lb. of balata, but it must be taken into consideration that the process can be annually repeated and the alternate pieces of bark taken off. The latex runs more abundantly during the rainy period, when the coagulation takes also more time. The native gatherers maintain the latex to be more abundant during a declining moon phase, an observation which prejudices also many European farmers. The latex, here called "purvio," is collected in wooden tanks, as iron tanks turn the material black and reduce the commercial value.

Raw balata is grey, brown, or whitish-red, with dark specks

and veins; it looks like dry hides and feels rough. Grey balata comes on the market in 30 × 15 inch blocks; red balata comes in sheets or plates from ½ to ¾ inch thick, and shows the shape of the tank in which the latex has been dried. The commercial balata contains few foreign substances and little bark, but the natives often adulterate the balata with salt and clay. The adulteration averages about 10 per cent. The balata of the *Mimusops balata* and the *M. globosa* is particularly valuable; it has the especial property of little elasticity, a point which makes it specially serviceable for driving-belts. The price for balata is, if not the same, higher than that for gutta-percha. It is difficult to obtain reliable commercial statistical data for balata.

Dr. E. F. Obach gives, in his repeatedly mentioned "Cantor Lectures on Gutta-percha," valuable statistical details about prices and exports of balata from English and Dutch Guiana. These details were taken from Government reports, reports of the Director of the Colonial Museum at Harlem, and a report of Consul Churchill of Paramaribo to the Marquis of Salisbury. The reports picture the trade for the years 1885-96 as follows:—

Export of British Guiana.			Export of Dutch Guiana.		
Year.	Cwts.	Value.	Year.	Cwts.	Value.
1885	496	£2,213			
1886	606	2,979			
1887	723	3,498			
1888	2,219	14,069	1899	30	£116
1889	3,245	15,625	1890	1,502	7,951
1890-1	2,025	10,078	1891	1,882	11,950
1891-2	1,039	6,807	1892	2,375	15,086
1892-3	2,120	11,296	1893	641	5,424
1893-4	1,832	8,283	1894	2,132	18,047
1894-5	1,876	11,484	1895	2,631	22,281
1895-6	1,424	8,923	1896	2,480	21,000
Total.	17,605	£95,255		13,673	£101,865

This shows the lowest average price for the period for British Guiana balata as 9.13 pence per lb. in 1885, and the highest as 14.17 pence in 1888, whereas the lowest Dutch average price for the same quantity is 9.07 pence for 1889, and the highest average with 18.14 for the years 1893 and 1896. These price calculations depend on the declaration value on the export market. The sale price at Liverpool, London, Marseilles, Rotterdam, and Hamburg, was not much higher, and oscillated in London between 13 pence and 30 pence per lb. for sheets and block balata.

For the period 1895-1901 the picture changed according to other sources in the following way :—

Export of British Guiana.		Export of Dutch Guiana.		
Year.	cwts.	cwts.	kilos.	Imported to Holland in kilos.
1895	1498	—	—	—
1896	2977	—	—	—
1897	3854	3137	195,253	120,323
1898	4629	2234	113,431	59,594
1899	1938	2336	118,601	117,769
1900	3687	4113	208,805	204,134
1901	3002	(?)	(?)	(?)

The principal markets for balata in Europe are London, Rotterdam, and Hamburg. The following statistics show the price movement on these import markets :—

Balata prices in London.

	Surinam leaf (per lb.).	Venezuela block (per lb.).
1897 . . .	2/ -1/7½	1/6¼-1/6½
1898 . .	1/6½-1/6 -1/9	1/3 -1/4¼ -1/2¾
1899 . .	2/4½-1/11-2/5	1/9½-1/5
1900 . .	2/4 -2/6½-2/5	1/9 -2/11 -1/8
1901 . .	2/5 -2/4 2/7½	1/7½-2/1
1902 . .	2/5 -2/7	2/1½-1/10½-2/2

Balata prices in Hamburg (price per kilo in Marks).

	Beginning	Middle	End of the year.
1897 . .	3.55-3.50	3.45	2.85-2.75
1898 . .	2.75-2.85	2.95	2.65
1899 . .	2.70	3.60	3.50-3.75
1900 . .	3.85	4.30-4.55	4.25-3.80
1901 . .	3.80	3.65-3.60	3.80-4.10
1902 . .	4.25-4.60	4.30-4.40	4.45-4.80

Balata Prices in Rotterdam.

Year.	Import in Tons.	Surinam Leaf: Price in Marks per Kilo.			Import in Tons.	Venezuela Block: Price in Marks per Kilo.		
		High-est.	Lowest.	Average.		High-est.	Lowest.	Average.
1897	153	4.85	3.65	4.20	60	3.70	3.50	3.60
1898	80	4.10	3.65	3.95	159	3.40	2.75	3.00
1899	95	5.30	4.10	4.50	52	3.15	2.90	3.10
1900	162	5.40	5.25	5.30	23	4.0	3.15	3.85
1901	212	5.80	5.35	5.45	31	4.0	3.75	3.90
1902	190	5.70	5.20	5.40	50	4.75	3.75	4.40

The figures for 1902 include only the first ten months

The greatest difference between gutta-percha and balata is shown in the influence of the air. Several qualities of gutta-percha become in the air comparatively quickly resinous, hard, and brittle, and this not only affects the surface but the whole substance, whereas balata remains for a long time quite unaffected. Balata is softer under ordinary temperature and does not become so firm as gutta-percha when cooled. Balata cools very slowly and transmits this peculiarity when mixed with gutta-percha. Heated, it gives the same agreeable smell as pure gutta-percha which has been heated under water and brought to a boiling-point. The specific weight of balata is 1.05, it can be cut like gutta-percha, but is much tougher than it. It can be fully dissolved in turpentine, benzin, and bisulphide of carbon when heated, but like caoutchouc it resists all corroding alkalies and also nitric acid. Balata carbonises

under the influence of sulphuric acid. At an ordinary temperature balata is a horn-like substance, but when heated to only about 125° F. it can be moulded to any shape.

If the commercial material is cleaned in boiling water with the addition of some acids, and then washed in boiling alcohol, a substance is obtained which, when dissolved in bisulphide of carbon, filtered and evaporised, gives, according to Sperlich, the same compound as gutta-percha :—

Carbon	88.5
Hydrogen	11.5

The manufacturing process of balata is similar to that of gutta-percha, the same apparatus and machinery can be used. In

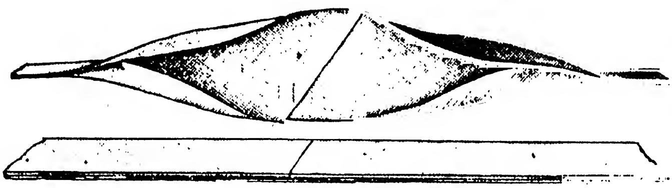


FIG. 30.—Endless join in Balata-belting.

some instances the method is more simple, because balata contains as a rule fewer impurities, and the articles made of it are not used for such special purposes. A simple washing in the rolling-mill or hollander is often sufficient preparation. A few qualities supply a very homogeneous substance when kneaded, but it retains too much elasticity, and remains adhesive. The purified balata is less smooth than gutta-percha, and if not mixed with the latter it can only be used for certain purposes. Unmixed, it cannot be used as covering for wires for insulation, and mixing with the best gutta-percha does not make it as suitable a material as pure gutta-percha even of second quality. The admixture of balata with gutta-percha and caoutchouc gives these on the other hand the needed properties for certain purposes. Balata is used independently of other materials for matrices and moulds for galvanic purposes, soles for boots, dress preservers, and preferably, for driving-belts, for which it is very suitable owing to its great toughness. These belts must not be used in too hot a temperature as they become sticky. The manufacturing process of balata belts is

analagous to that of rubber belts. As in the case of rubber belts the best cotton tissues are used, and these are brushed over with prepared material on a calender. As many layers as are needed are placed one upon another, and sown longitudinally to give them a better grip, a cover sheet is added and the whole product placed under strong pressure. The belts need no vulcanisation, a point hardly worth mentioning. It is an advantage in some localities that these belts can easily be joined. To make a good joint the two ends are heated until they become sticky; the layers of the belts are loose under this condition and the ends are placed one upon another. The edges are now laid one on another, at an angle of 45 degrees, for about an inch, pressed out with an iron, and the connected belt is replaced in its old folding, and the joint part is pressed or ironed. As soon as the joined piece had become cool it can be used, and runs as an endless belt without a jerk. For this reason balata belts, joined by this method, are of special use for driving dynamos.

List of the Principal Articles made of Indiarubber, Gutta-percha and Balata.

1. Soft Rubber.

1. Articles for Technical Purposes.

(a.) Packing materials.

Rubber sheets with or without inside layers or covers of hemp, flax, cotton, jute, or asbestos texture, of lead, brass, or iron-wire gauze; with or without inside layers or covers of tinfoil; all these also combined with asbestos, for steam, water, gas, and acid packings; condensation rings, discs, or ropes for the same purposes; man-hole discs and ropes; stuffing box covers; greased cotton ropes with rubber wire; rings of solid and hollow rope (compression rings, etc.), or of hose (water gauge rings, etc.).

(b.) Valves, buffers, pads, etc.

Pump and valve lids for hot and cold water, etc.; bellows lids; pump and other valves; cups for hydraulic presses; cones for vacuum lockers; stoppers for chemical laboratories; buffers for rail and tram carriages, etc., and for all kinds of shock or pressure; brake blocks.

(c.) Hose.

Suction and pressure hose with or without inside layers or covers of hemp, flax, cotton, jute, or asbestos texture; with or without an inner or outer spiral of metal plaiting, etc., for water (garden and street watering, fire-engines), steam (pile box, heating tubes for railway carriages), acids, wine, beer, oil, petroleum, gas, compressed air (Carpenter and Westing-house brakes), etc.; tubes for windows and doors, with or without grooves; gummed hemp and cotton hose for salvage purposes; gummed hemp spiral hose.

(d.) Driving-belts and ropes

for all kinds of transmission; elevator straps, conveyer belts for silo store rooms, sugar refineries, ore and coal mines, dredging machines, etc.

(e.) Roller covers

for all kinds of rollers used in paper factories, woollen and cotton mills, leather factories, cotton printing works, for wringers, typewriters, and printing machines.

(f.) Pneumatic and solid tyres

for cycles, carriages, cabs, automobiles, etc.; wheel covers for transport cars, trolleys, etc.; pedal and other rubber parts for cycles.

(g.) For electrical purposes.

Rubber tapes for cable factories; insulating bands; split tubes; gloves for engineers, etc.; insulation caps for telegraph poles, etc.

(h.) Other special articles.

Printing cloth, card, and other cloth, for spinning and printing mills; endless cloth for carrying machinery; Retinier sheets for cloth factories; cover cord and bolting leather for paper mills; hat shapes; sinking funnels for sugar factories; catch straps; gas bags for gas motors; gas stop bladders; malting soles and boots; acid balloon clearer; caoutchouc lac for waterproofing paints and as preventative against fur in boilers; rubber solution as sticking paste.

2. Articles for Surgical and Nursing Purposes.

Air and water bags; seating, heel, head, throat, back cushions, etc.; air and water beds; bed-pans; ice bags; baby bottle rubbers; tooth rings and cushions; milk pumps; cuppers; dropping counter; eye, ear, nose, and clyster syringes; probes, pessaries; palottes; urine bottles; bandages of all kinds; arm and muscle developers; gloves for operators; single and double-gummed bed-sheeting, also double material with inside rubber layers.

3. Articles for Household and General Purposes.

(a.) Mats and floor covers.

Solid or perforated; washstand and bathroom carpets.

(b.) Special articles.

Billiard-table cushions; skittle balls; door stoppers; air pushes for pneumatic bells; pneumatic hangers for shop windows; signal lamps; horse shoes with rubber buffers; shoe protectors; stirrup inlayers; curb chain protectors for horses;

brake blocks for carriages; bottle-stoppers of all kinds; preserve glass covers; erasing rubber; rubber stamps; copying leaves; rubber bands for pocket-books, papers, arm bands and garters, etc.; thread rings; umbrella rings; tobacco pouches; drink and dice cups; bathing tubs; bathing caps; swimming belts; hot-water bottles; bellows for perfume sprayers; dress preservers; balloons and rubber balls; dolls and figures.

4. Elastic Cloth.

Straps, belts, and ribbons of all kinds; threads surrounded with thread; braces, belts, garters; elastic cloth for boots, etc.

5. Waterproof Materials, etc.

Single faced and double faced mackintoshes; double cloths with rubber encloser; single and double rubber for air balloons; air balloons; bed-sheeting; bags for dynamite and powder; gas and air-bags; covers for railway and other carriages; ship covers; barrack blankets; horse blankets; travelling rugs for carriages and sledges; tents; weather cloths.

6. Waterproof Clothes and Boots.

Rain-coats; caps; gaiters; aprons; perfect outfits for divers, miners, sailors, anglers; southwesters, hats, and caps; rubber galoshes and boots of all kinds; gymnastic and tennis shoes; shoe soles and heels.

II. Hard Rubber.

1. Articles for Technical Purposes.

Plates, sticks, sheets, tubes, muffs, flanges, curvatures, knee-pieces, and pieces for connections; suction and press pumps (fly and membrane pumps); air chamber; funnels; suction baskets; syphons; receptacles of all kinds; outfits for centrifugals, drums, evaporating pans, and vessels of all kinds; spinning rolls (booses'); rollers; accumulator cases, battery cells; insulation caps; insulation tubes; telephone mouthpieces and cases; handles and cranks for electrical and other apparatus, etc.

2. Articles for Surgical Purposes.

Syringes; stethoscopes; audiphones; eartubes, and instruments of all kinds.

3. Articles for Household and General Purposes.

Skittle bells; trays for bottles and glasses; sprays; drinking cups; paper-folders; rulers, curves, and angular pieces for draughtsmen; knife handles; shells for sable handles, pistol and rifle butts; handles of all kinds; weights and trays for scales; powder spoons; mouthpieces for whistles and speaking-tubes; walking-sticks; buttons; thimbles; needle-cases; match-boxes; combs; jewellery, brooches, earrings, bracelets, watch chains, medallions, etc.

III. Gutta-percha.

I. Articles for Technical Purposes.

Plates, sheets, rings, ropes, discs, etc., for cold-water packing; cuffs for hydraulic presses; cups and capsules for pumps; acid pumps; driving-belts and ropes; tubes; suction baskets; taps; funnels; bottles, stoppers, tubs, pails, cups, watering-pots; siphons, trowels, saddles, diving sticks, etc.; measures and weights; washing drums; spinning rolls; matrices; roller covers; discs for glove factories; Chatterton's compound; ignition fuses; gutta-percha veins for cable factories.

2. Articles for Surgical Use.

Gutta-percha paper for compresses and bandages, also for hat, cloth, and flower factories; ear tubes; probangs and probes; tooth enamel; urinal bottles, chamber pots, and washing basins for asylums, etc.

3. Articles for Household Purposes.

Trays for glasses and bottles; mouthpieces for whistles and speaking-tubes; sticks and riding-whips, etc.

IV. Balata.

Driving-belts; dress preservers; shoe soles; sheets, ropes, rings, etc., as for gutta-percha.

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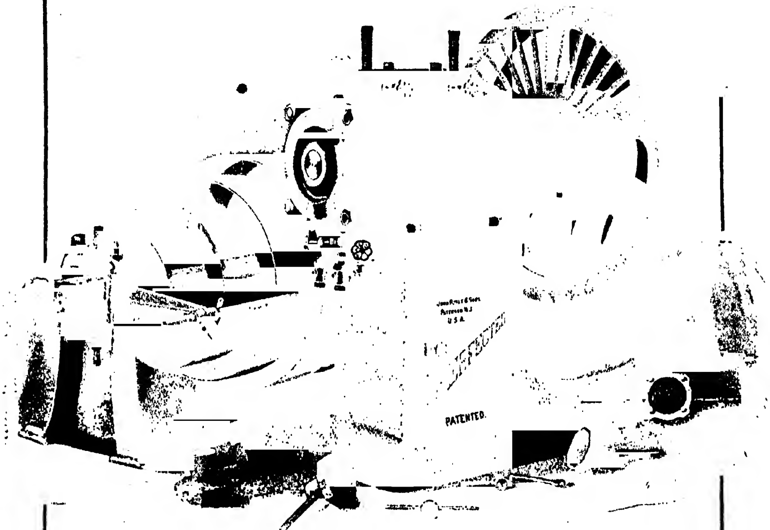

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